METHODS OF IDENTIFYING AND RENOVATING BUILDINGS TO ACCOMMODATE NATURAL DISASTER NEEDS IN EAST COAST REGIONS IN THE UNITED STATES

by

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As members of the Master's Committee, we certify that we have read the thesis prepared by Dominique Relei, titled Methods of Identifying and Renovating Buildings to Accommodate Natural Disaster Needs in East Coast Regions in the United States and recommend that it be accepted as fulfilling the dissertation requirement for the Master's Degree.

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Final approval and acceptance of this thesis is contingent upon the candidate's submission of the final copies of the thesis to the Graduate College.

I hereby certify that I have read this thesis prepared under my direction and recommend that it be accepted as fulfilling the Master's requirement.

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3. Application of Methods Pennsylvania Convention Center

Abstract

As the world continues to see an increase in Natural Disasters, there is a need for disaster preparedness now more than ever. Through the retrofitting of existing large-scale buildings with a design approach that considers: location, structure, and program people in need would have a place of refuge prior to the occurrence of a disaster. Utilizing specific large-scale public buildings such as stadiums, or convention centers chosen by the above criterium. Allocating, spaces for various uses and equipping them through the development of a two component methodology created to help local governments investigate means of designing buildings to accommodate victims of all different disaster conditions relevant to the region. The two components which are building identification and building programming, address the designation of buildings and procedure to ensure optimal execution and function in response to the needs of the disaster type. Which addresses areas in the United States prone to floods, and hurricanes. Specifically, in the Gulf and East Coast Regions.

Keywords: Disaster preparedness, methodology, renovation, retrofit.

Acknowledgements

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Dedication

For my mom.

Chapter 1: Introduction to Natural Disasters

1.1 Definitions

Natural disasters occur suddenly, and involve various types of severe weather. They include earthquakes, hurricanes, flooding, winter storms, tornados, and wildfires. Hurricanes and floods are so severe that they have the ability to destroy cities, and disperse large groups of people. They are uncontrollable, and become more frequent during specific times of the year; such as, the Atlantic hurricane season which lasts several months from June to November[1]. During this time various regions in the United States and around the globe are at risk in both inland areas and coastal regions. With Hurricanes come incredibly strong winds, and periods of heavy rainfall. According to the Department of Homeland Security, "Ninety percent of natural disasters within the United States involve flooding[2]."The following research focuses on the areas in which the blue and orange regions overlap; as seen in the United States Natural Disaster Map in figure 1 below.

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[1] Tropical Cyclone Climatology. (n.d.) Retrieved 2019, from https://www.nhc.noaa.gov/climo/

[2] Natural Disasters. (2018, May 04). Retrieved January, 2019, from https://www.dhs.gov/natural-disasters

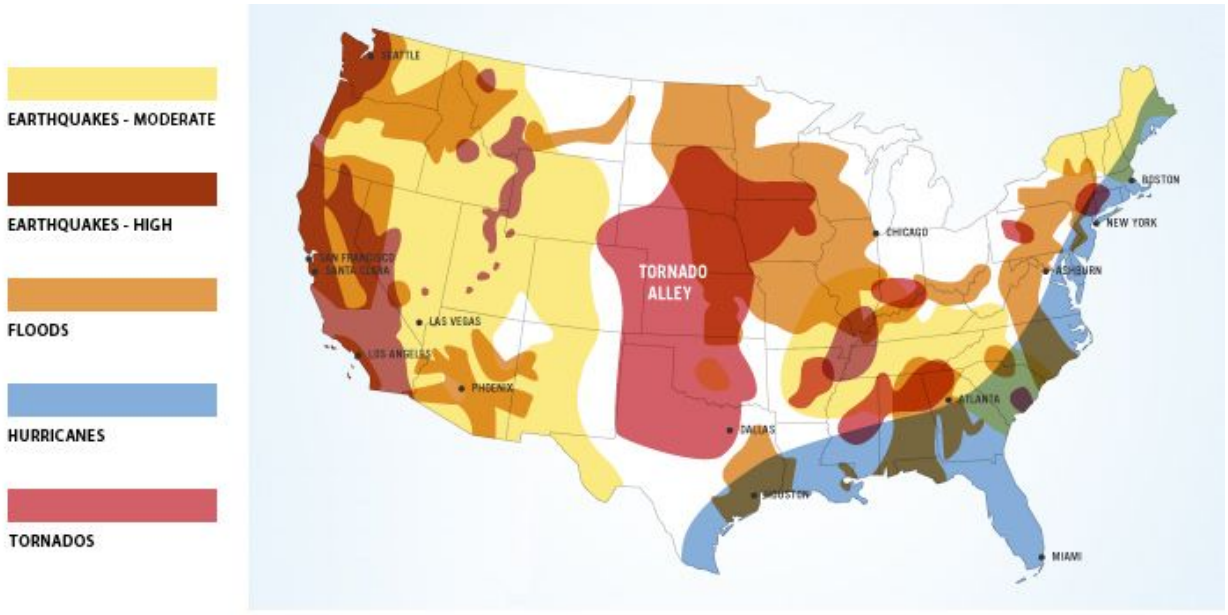

Figure 1 United States Natural Disaster Map[3]

1.2 Personal experience

At the age of seven our family had a house fire on Christmas Eve. My sister and I had went to visit family on holiday and on the way back from the airport our mom explained to us that everything we had had been lost in the fire. All we had was each other, and the suitcases that we had gotten off the plane with. In that moment, I remember feeling like I had lost so many things that I greatly valued, and there was no way for me to have prepared for it. What I did understand however; was that we still had each other. In the next few weeks and months that followed we slowly began to repair our lives. It is from this experience that my passion for this topic comes from. As we struggled to piece back together our lives so many others go through the same experience, when a disaster strikes.

[3] NOAA, and RedCross. "SG Alert Systems Group." Digital image. Accessed 2019. http://alertsystemsgroup.com/earthquake-early-warning/informative-maps/.

1.3 Problem Statement

Displaced. Distressed. Dependent. Three words that are at the core of those impacted by natural disasters. While technology has advanced to the point that predictions can be made as to when disaster may strike; there is still no way of knowing how profound the impact will be and exactly when it will occur. Those who cannot leave the area of risk for whatever reason, are left at the mercy of the disaster itself. Others are relocated to evacuation centers somewhere in their cities, which are often educational institutions or small facilities that are no more equipped than the homes many left[4]. Often, when these shelters become overcrowded, large scale buildings such as stadiums and auditoriums serve as a hub for those in need[5]. Post disaster canvas tents are brought in and erected on site; as well as, temporary trailers that serve as sleeping quarters and clinics that provide basic survival supplies. Response organizations such as the Red Cross and FEMA provide aid with little preparation time and often come to aide the thousands displaced after the disaster has occurred. However, it does not have to be this way. In order to better understand how to prepare for future events, past case studies must be analysed. To understand how the needs of those recovering from the Natural disaster were and were not met with the architecture available to them.

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[4] Wtvd. (2018, October 04). Florence: List of area shelters, emergency operations centers open. Retrieved from https://abc11.com/weather/florence-list-of-area-shelters-emergency-operations-centers-open-/4211642/

[5] Grano, D. A., & Zagacki, K. S. (n.d.). Cleansing of the Superdome: The Paradox of Purity and Post-Katrina Guilt. *Quarterly Journal of Speech, 97*(2), 201-223

Figure 2

1.4.1 Hurricane Sandy

Hurricane Sandy occured in 2012 and has been labeled as "one of the damaging hurricanes ever to make landfall in the United States," [6] a combination between the sediment and water can be seen from NASA's Suomi NPP satellite image October 30TH, 2012 in figure 3[7].

Figure 3

[6] Gibbens, S. (2019, February 25). Hurricane Sandy, explained. Retrieved May, 2019, from https://www.nationalgeographic.com/environment/natural-disasters/reference/hurricane-sandy/

[7] "Sediment from Hurricane Sandy." Digital image. NASA Earth Observatory. October 30, 2012. Accessed May 2019. https://earthobservatory.nasa.gov/images/79607/sediment-from-hurricane-sandy.

The tropical storm began in the Caribbean then progressed to a category 3 hurricane with 11-129 mph winds, a breakdown of the storms progression have been illustrated in utilizing data from the Saffir-Simpson Hurricane Wind Scale in figure 4 below[8]. Categories 3-5 are considered to be the most dangerous as structural integrity may become threatened and loss of life is possible[9].

Figure 4

While various regions around and across the United States were devastated, this section looks specifically at the five boroughs of New York. As their geographic location bears further insight into the methods that will be discussed later in this study. With little time to evacuate days before the disaster hundreds of thousands of residential areas located in areas of lower elevation; as well as, coastal and floodplain regions of the state were ordered to evacuate.

[8] Chickering, Helen. "Hurricane Categories: Missing The Big Picture?" BPR. September 2017. Accessed May 08, 2019. https://www.bpr.org/post/hurricane-categories-missing-big-picture-0#stream/0.
[9] US Department of Commerce, and Noaa. "Saffir-Simpson Hurricane Scale." National Weather Service. September 08, 2016. Accessed May 11, 2019. https://www.weather.gov/mfl/saffirsimpson.

More than 600,000 people were listed as being in evacuation zones[10]. The 45,000 of the 370,000 homes who had to leave were in public housing. In order to get them out of the region prior to the disaster, hot water heating and elevators were turned off. This hurricane hit the the East coast with just 80 mph winds as a category 1; bringing with it flooding and enough damage to leave millions without power stranded, and in need of help. In New York city alone a million people were left without power[11].

Thousands of the sick and elderly were stranded in high rise buildings since elevators became inoperable. Numerous homes were destroyed in the Staten Island area. 90 percent of Long Island was left without power. In Manhattan tunnels flooded, and subways were shut down; in Queens the flooded electrical systems generated a fire that burned down a residential areas. Also, the existing 230+ municipal homeless shelters were located in the evacuation zones. Meaning that, "1,200 homeless single adults and 300 homeless families" had to be relocated to relief shelters somewhere else in the city, which were almost at max capacity[12]. What can be taken away from these studies? From an economic perspective the areas hit the hardest were those in public housing. Financially 45,000 people did not have the resources to go somewhere else; and the homeless shelters that could have been another option for them were almost full. Where does this leave them? In their homes without power, water, and at extreme risk. If they survive the storm, maybe hope will come.

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[10] "Larger Evacuation Areas in New York City." The New York Times. June 18, 2013. Accessed May 08, 2019. https://archive.nytimes.com/www.nytimes.com/interactive/2013/06/18/nyregion/Larger-Evacuation-Areas-in-New-York-City.html?ref=nyregion.

[11] "Hundreds of Thousands Ordered to Evacuate as Sandy Bears down on East Coast." NBCNews.com. October 29, 2012. Accessed May 08, 2019. http://www.nbcnews.com

[12] Markee, Patrick. "Homeless New Yorkers and Hurricane Sandy." Coalition For The Homeless. November 2012. Accessed May 08, 2019. https://www.coalitionforthehomeless.org/homeless-new-yorkers-and-hurricane-sandy/.

1.4.2 Hurricane Harvey

Hurricane Harvey hit the SouthEastern part of Houston Texas in 2017. Houston is in a subtropical region of Texas. The downtown area of the city is ranged from 2-40 feet above sea level; with varying elevations surrounding it.The rain that followed the tropical storm reached record levels for days following the event. With the entire city area under water; the coastal regions were hit the hardest. One of the many reasons why that the water stayed in the Houston area, was due to the low-lying infrastructure of the city. The city itself is set up in such a way that the drainage is a combination of a bayous flowing into the Houston Ship Channel; so when these overflow it adds to the flooding of the area. As the population of Houston increased, the surrounding wastelands were developed on. Meaning that, if the wetland area had been left exposed and not developed on it would have acted as a sponge to absorb some of the rain. However, in its place asphalt was implemented which made water flow and buildup even more intense.

In the aftermath of the tropical storm on the East Texas-Louisiana border with drainage channels overflowing; 35,000 people were in shelters five days after the storm. The number, and range of people in the area vary greatly[13]. In the most densely populated areas both the the southwest and west regions along Interstate 610 levels reached over 8 feet in depth; on the north side not far from the George Bush Intercontinental airport water exceeded in depth to over 10 feet. More than 850,000 homes in the area were flooded. The affected populations also included the counties 430,000 residents who exceeded the age of 64; as well as, the 367 assisted-living

[13] Cameron, D., Alcantra, C., Florit, G & Berkowiz, B. (2017, September 1). Flooding spreads eastward as Harvey bombards Louisiana. Retrieved April 28, 2018, from https://www.washingtonpost.com

facilities. Residents who didn't speak English or are of undocumented immigrant status, struggled understanding evacuation plans, and flood warnings as laws regarding sanctuary cities were in the process of taking effect. Children and minorities were located in the northeastern and eastern parts of the city along the Halls and Greens Bayou with water levels ranging above 6 feet. Gauge station channels--that regulate water amounts reading at anywhere from two to forty feet in depth[14]. In figure 5 released by the U.S. Department of Defense, photographed by Zachary West depicts a flood rescue by the Texas National Guard assisting those affected by Harvey in Houston late August 2017[15].

Figure 5

[14] Lu, D., & Williams, A. (n.d.). Houston's floodwaters are receding, but they remain dangerously high in many areas. Retrieved January, 2019, from https://www.washingtonpost.com/graphics/2017/national/harvey-houston-flooding/?utm_term=.595811e2c4ca

[15] West, Zachary. "Flood Rescue." Digital image. U.S. Department of Defense. August 27, 2017. Accessed May 2019. Grisham, Jeremy. "US Navy 050831-N-8154G-198 A Man Carries a Baby through.

1.4.3 Hurricane Katrina

The state of Louisiana, is a humid subtropical region as seen in the United States map of Köppen Climate Classification figure 6[16]. New Orleans which is located at the southernmost part of the State receives an average annual rainfall of 7.5 inches in July-with average annual temperatures ranging from high of 78 degrees fahrenheit toa a low of approximately 61 degrees fahrenheit. The prevailing wind is coming into the city from the is East/South East part of the state-the wind rose indicates how many hours per year the wind is blowing from the indicated direction[17]. Each year the Atlantic hurricane season lasts from June 1st to November 30th. The city is below sea level and located along the coast[18]. Hurricane Katrina hit this region late August 2005. Katrina was a category 5 Hurricane with wind speeds over 175mph, with storm surge flooding. Figure 8 from the Louisiana Department of Transportation and Development below depicts a satellite image of the flood prone areas for this areas of New Orleans. As can be seen from the figure the Superdome number one and Scooters Chicken arena is below it both are very close to both the Mississippi River as well as a are in a low lying area depicted in the blue in figure 7[19].

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[16] https://en.wikipedia.org/wiki/File:USA_map_of_Köppen_climate_classification.svg#filelinks
[17] FTP Access to Wind Rose Plots (1961-1990). Accessed May 09, 2019. https://www.wcc.nrcs.usda.gov/ftpref/downloads/climate/windrose/louisiana/new_orleans/.
[18] Love, M.R., C.J. Amante, L.A. Taylor, and B.W. Eakins. "Digital Elevation Models of New Orleans, Louisiana: Procedures, Data Sources and Analysis." *NOAA Technical Memorandum NESDIS NGDC-49*, August 2011. Accessed 2019. ftp://ftp.library.noaa.gov/noaa_documents.lib/NESDIS/NGDC/TM/NOAA_TM_NESDIS_NGDC_49.pdf.
[19] La DOTD - Floodplain Management Contacts. Accessed May 09, 2019. http://floods.dotd.la.gov/lafloods/.

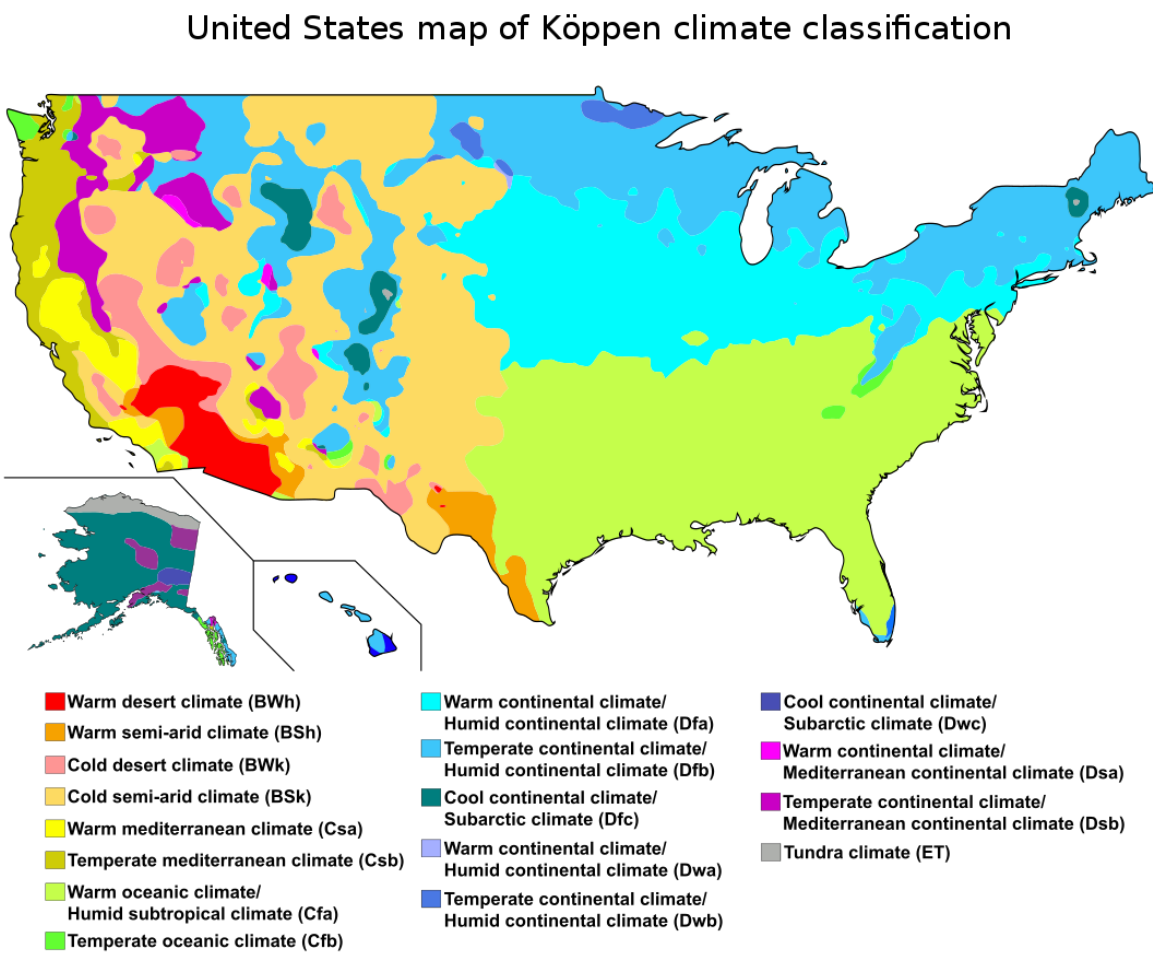
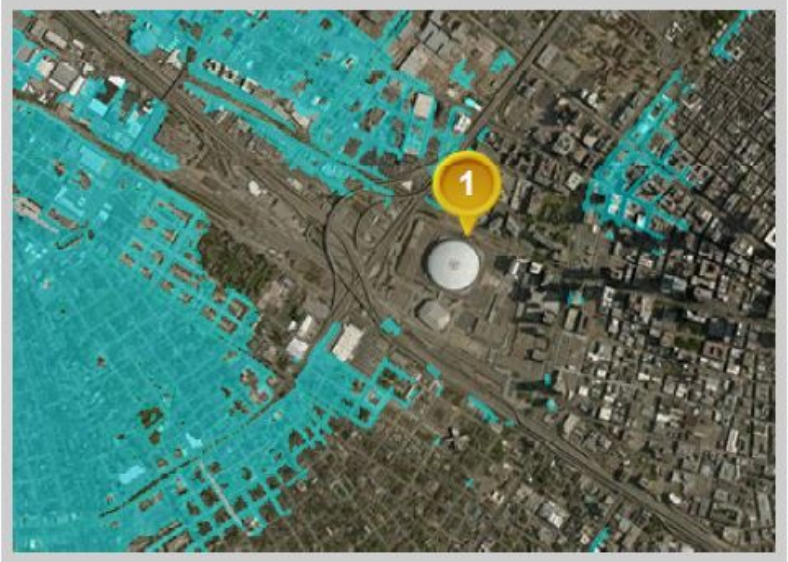


Figure 6 United States Climate Map[20]

[20] "File:USA Map of Köppen Climate Classification.svg." File:USA Map of Köppen Climate Classification.svg - Wikimedia Commons. Accessed May 13, 2019. https://commons.wikimedia.org/wiki/File:USA_map_of_Köppen_climate_classification.svg.

Louisiana Flood Map

1500 Sugar Bowl Dr, New Orleans, LA 70112



Visible Layers

- Effective FIRM
- Bing Aerial

Point Coordinates

Point #	Lat., Long.
1	29.9523, -90.0805

Figure 7

In order to learn from this case study, there are areas that were both successful and unsuccessful taking into consideration these criterium: location, structure, and program. The Mercedes-Benz Superdome located at 29 degrees Latitude and -90 degrees Longitude in New Orleans Louisiana has a total floor area of 269,000 square feet and is 253 feet high. With a capacity of 74,295 it served as a refuge and last resort for approximately 30,000 evacuees during Hurricane Katrina which struck the region in August 2005[21]. The Superdome served as a central landmark and location in the city, located near 1-10 and the Scooters Chicken Arena and the Mississippi River. The Scooters chicken arena was un overflow area as well as a designated space for special needs evacuees until the structure became unsafe-due to additional flooding.

[21] Mercedes-Benz Superdome Facts & Figures. (n.d). Retrieved 2019, from http://www.mbsuperdome.com/assets/doc/presskit-1-874851cf94.pdf

Those in the dome and scooters arena were later evacuated to the Astrodome a state away in Texas. An image released by the U.S Navy taken by Mate Airman Jeremy Grisham, depicts a man with child outside the Superdome stadium figure 8[22].

Figure 8

As the city of New Orleans is below sea level. The levee system that was designed to protect the city from additional flooding failed. Causing breached levees, "Flooding approximately 75% of the area figure.[23]" Three of the main failures were due to the soil failure the levees were built on-resulting in failed foundation-letting water in. Transitions in higher and lower levees also created a weak point-and proved ineffective as a flood protection System, as

[22] Grisham, Jeremy. "US Navy 050831-N-8154G-198 A Man Carries a Baby through the Flooded Streets of New Orleans outside the Cities Superdome Football Stadium." Digital image. Https://commons.wikimedia.org/wiki/File:US_Navy_050831-N-8154G-198_A_man_carries_a_baby_through_the_flooded_streets_of_New_Orleans_outside_the_cities_Super_Dome_football_stadium.jpg. August 2005. Accessed May 2019.

[23] Kayen, Kayen, Robert et al. "USGS Scientists Investigate New Orleans Levees Broken by Hurricane Katrina." *USGS,* Jan. 2006. Soundwaves, usgs.gov/2006/01/.

can be seen in figure 9[24] in the City of New Orleans Ground Elevations the Hurricane protection and leevy floodwall along the Mississippi broke due to the water swelling, which caused additional flooding to the area. The Superdome was not technically in the floodplain region-however due to the levy failure the Mississippi river continued to rise flooding the surrounding area. The Louisiana Superdome occupant area was also built on a three-story platform which served as the facilities parking. Elevating the occupant portion of the facility approximately 30' above ground level. As far as the Structural integrity of the space. The Superdome roof was designed to withstand approximately 200 mile per hour wind speeds[25]. However, the 145 mile per hour wind speeds of Katrina would have ripped the roof off hand not been for the media center which acted as an interior counterweight. This did not eliminated water from coming into the facility. After explaining the context for this event. The human experience for those who sought refuge in this space was terrible. For five days during the storm those inside experienced a lack of ventilation, medical care, food and water, electricity, and access to restrooms or showers. Numerous assaults and a shooting took place during that time. Various interviews have described the stench and terror of the experience. Those located in the Superdome were later relocated temporarily to the astrodome in the neighboring state of Texas.

[24] "New Orleans Elevations." Digital image. Https://commons.wikimedia.org/wiki/File:New_Orleans_Elevations.jpg. May 7, 2009. Accessed May 2019.
[25] Mercedes-Benz Superdome Facts & Figures. (n.d). Retrieved 2019, from http://www.mbsuperdome.com/assets/doc/presskit-1-874851cf94.pdf

Figure 9

1.4.4 Cajundome and Superdome

A second case that took place during the same time period as the Superdome but was handled differently was the Cajundome which served as a hurricane shelter during hurricane Katrina. At 30 deg N latitude and 92 degrees west longitude. The average annual rainfall of the city is slightly less than New Orleans as it is located more inland-with average high of 92 and average low of 43 degrees. Since it is inland it is located at 36 feet above sea level. Which creates an advantage in this Gulf region. The Cajundome has a 37,300 sq. foot space with approximately 20,000 sq. feet dedicated to banquet area. Number one is the Cajundome number two is the main road for access and number three is the convention center which served as additional space. During hurricane Katrina this area was far enough away from the epicenter of

the storm that is served as a shelter for 18,500 people over the course of 60 days working in partner with the Red cross to provide sleeping arrangements and medical care[26]. From the second case study, and the first it is clear how much architecture influences the success or failure of providing much more than safety for its occupants. Those who were relocated to the Cajundome from their initial homes were able to find a place that was safe from the elements. As there was regulation and order, they were physically safe from the harm of others. The space was equipped with working restrooms and showers, food, and blankets were ready for those coming in to receive them[27]. It is because of architecture chosen by location and equipped for those in need, that this was a successful effort. The Cajundome was able to service 18,500 people, within the 37,300 sq. foot space figure 10. However, there was no separation between private and public sleeping areas, or spaces designated for medical use, everything was in a shared space, comparison based off of previously referenced case studies above.

Cajundome	**Superdome**
Hospitality	Hostility
Available Staff	Law enforcement
Fresh meals provided	?
Occupants treated with respect and kindness	Occupants treated with suspicion

Figure 10

[26] Taylor, C.(2016, August 29). How the Cajundome changed the future of aid after Hurricanes. Retrieved from http://www.theadviser.com/story/news/local/2015/08/21/katrina-cajundome-set-standard/32149231/
[27] Inbid.

Chapter 2: 2.0 Methods of Investigation

Based on my research, a two component methodology has been developed that helps local governments investigate means of designating buildings that help accommodate victims of all ages under different disaster conditions relevant to the region. The two components are, building identification and building programming. Building identification, is a process developed by the author to identify and designate buildings with the highest potential to adequately meet the needs of the region prone to the type of disaster. Building programming is a specific procedure relevant to programming spaces, within the designated building to ensure optimum execution and functional emergency response needs.

2.1 Building identification

The selection of a large facility such as a building or stadium that will adequately reflect the disaster at risk. In order to safely accommodate a significant amount of the local city's recipients, close enough to be accessible by various modes of transportation. As well as within distance to additional storage facilities. Building identification is broken down into 6 sub categories which are: building type, building location, site accessibility, structural integrity, large occupancy, and staging and or storage.

2.1.1 Building Type

In order to understand why a particular facility was chosen for this methodology one must compare and contrast the pros and cons of different buildings to see how that they comply with the needed criteria. A hospital, for example would be beneficial as it has medical supplies, emergency related equipment, and a full-service kitchen or cafeteria for patients. It would not however, be an adequate choice as it is a sterile environment, has strict building code restrictions that require more air changes per hour thus a more efficient HVAC system which creates more of a load on the building, which makes energy consumption during a natural disaster even more of a problem, lastly there is a very rigid floor plan that does not allow for the flexibility needed to accommodate the necessary program this can be seen in figure 11 below.

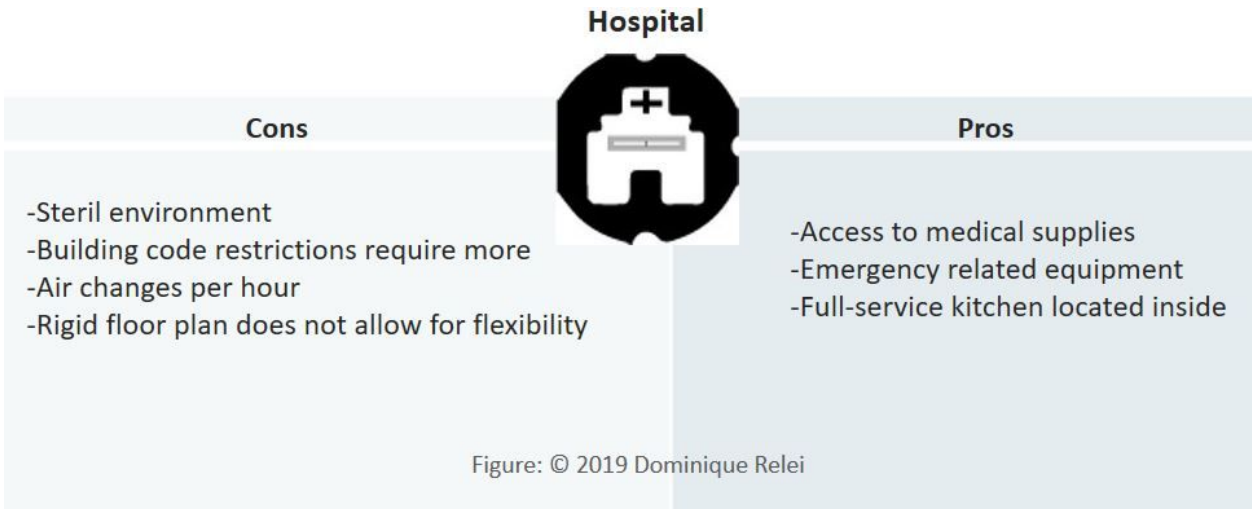


Figure 11

Next, taking a look at a different building type like a hotel. Hotels would be a beneficial choice as they often have a large occupancy, are equipped with an eatery or kitchen to serve guests, and have a parking lot on site or in close proximity to the facility. However, hotels are

privately owned not public facilities which means that they are not optimal to act as response centers, sleeping quarters and restroom areas are coupled together to create separate units and are permanent not allowing for flexibility of space, and lastly hotels are often high-rise buildings which is not optimal for this disaster type as has been seen in previous case studies considering the high-wind conditions we are addressing see figure 12.

Figure 12

Lastly, looking at convention centers to see how that they respond to the above methodology. Convention Centers are public buildings which are optimal to act as relief centers during natural disasters, they have a open floor plan, and are design to accomodate for various types of events. The occupancy of these buildings ranges from 10,000 to 100,000 people depending on the allotted square footage of the space, as can be seen from the various case study occupancy rates discussed above. As they are public buildings they are often in a Central location of the city and most always accessible by multiple forms of public transit. Also, a food service space is located inside the facilities to cater to the needs of various events. One of the

only concerns with the building selection of a convention center is making sure that the building envelope adequately responds to the disaster type. For example, a convention center whose exterior is entirely designed with curtain wall glass facades on all sides, while it is aesthetically pleasing is not practical nor reflective of the disaster addressed in this research and therefore would not adequately comply with this methodology. Simplification of the methodology in reference to this building type can be seen below in figure 13.

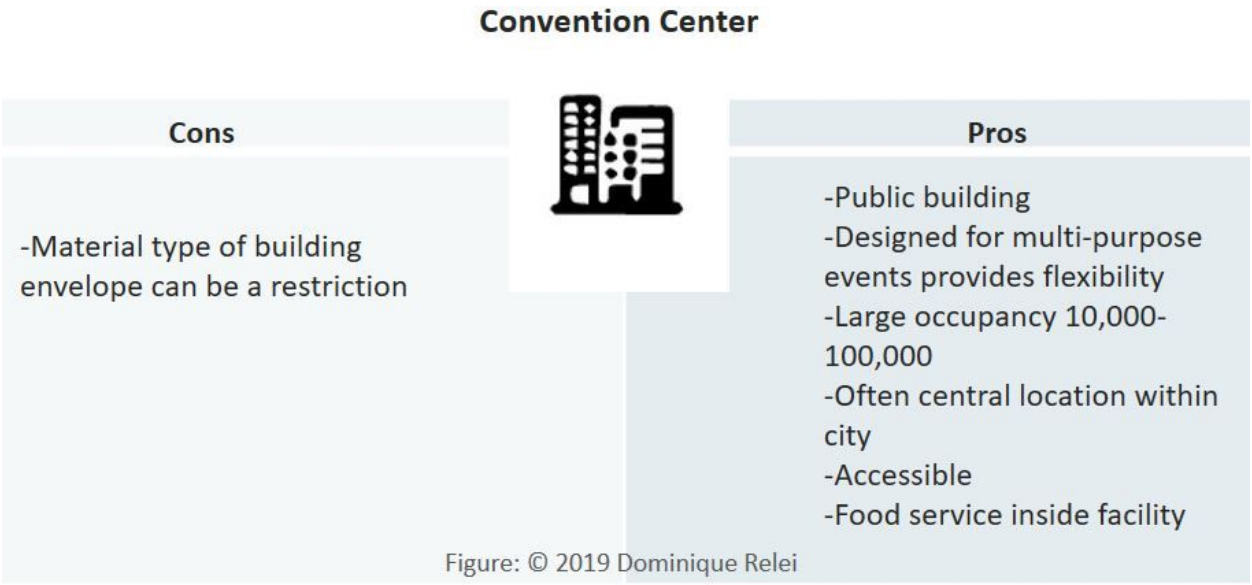


Figure 13

In order to address all of these considerations holistically a combined list can be found in figure 14.

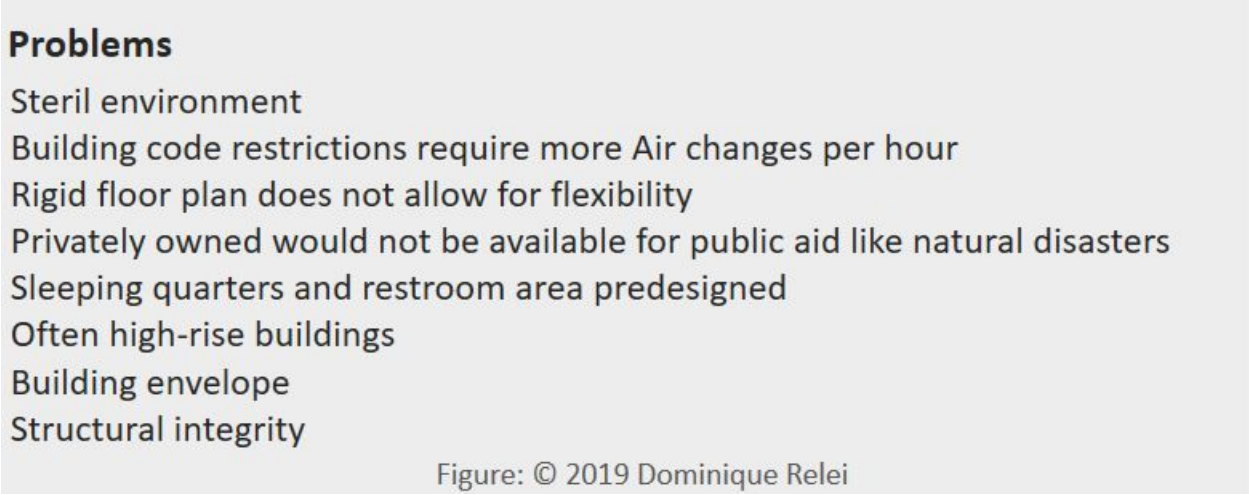


Figure 14

2.1.2 Building Location

In the case study of Hurricane Katrina, two different buildings were analysed and both had different results. The Superdome was located towards the tip of the state of Louisiana. Where the Cajundome was located more inland toward the central part of the state. Since, the impact on each facility greatly differed; the relationship between building location and the nature of hurricanes as they move inland that must be analysed. The ocean temperatures combined with high dew points which are the air above the ocean reduces as soon as the storm migrates away from the the ocean to the land. Since the land itself creates resistance it significantly reduces the wind speed and category of the storm[28].

[28] Kossin, James P., and Matthew D. Eastin. "Two Distinct Regimes in the Kinematic and Thermodynamic Structure of the Hurricane Eye and Eyewall." *Journal of the Atmospheric Sciences* 58, no. 9 (2001): 1079-090. Accessed 2019. doi:10.1175/1520-0469(2001)0582.0.co;2

Therefore, the site must be located far enough from bodies of water that may be a possible threat, such as levees or coastal areas as can be seen in figure 15.

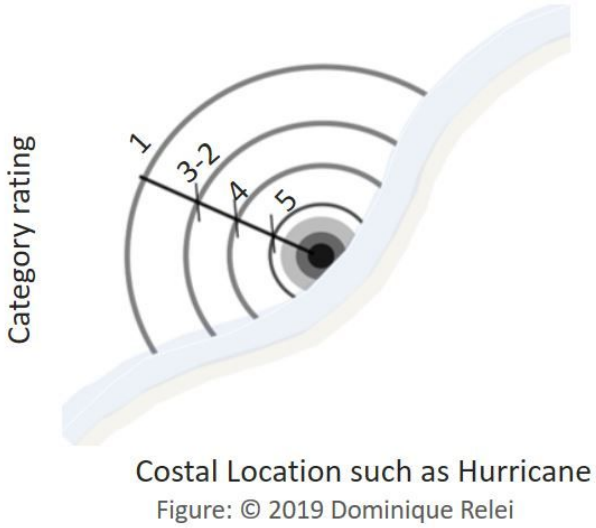
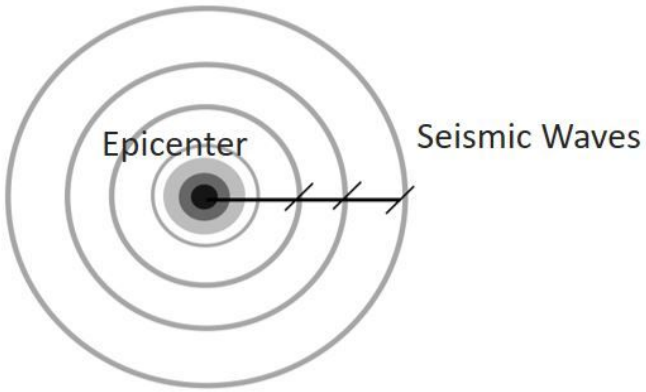


Figure 15

It also must be centrally located in the city of the projected need. It must also be accessible by multiple forms of transit. It is also important to reflect on the nature of natural disasters when looking at a earthquake for example. When an earthquake occurs from the epicenter of the quake or area where the plates rub together seismic waves are then triggered. Unlike a hurricanes which slow down when they come into contact with land, seismic waves are unpredictable as to their frequency and can occur either hours, days, or minutes apart see figure 16.



Inland such as Earthquake

Figure: © 2019 Dominique Relei

Figure 16

2.1.3 Site Accessibility

Qualified building sites must consider results from current evacuation simulation model testing.[29] According to the United States Department of Commerce, in partnering with the National Institute of Standards and Technology and Technology Administration in their publication *Modeling and Simulation for Emergency Response: Workshop Report, Standards and Tools* "multi-zonal models and computational fluid dynamics approaches" are currently being tested in order to create strategic plan that is efficient to utilize during emergency situations[30]. Which are based off, city evacuation plan based off of zone division, population density and geographic barriers.

[29] Nutter, Michael, Everett Gibson, and Liam O'Keefe. "Evacuation Routes Map." *Evacuation Routes*, August 2011, 1-30. Accessed 2019.
[30] United States of America. Department of Commerce. *Modeling and Simulation for Emergency Response: Workshop Report, Standards and Tools*. By Sanjay Jain and Charles R. McLean. 1-116. Accessed May 2019.

Therefore, in accordance with the methodology established by the author in order to provide access to emergency response vehicles and FEMA efforts, main roads to the site must be clearly marked within a 5-mile radius. Furthermore, in order to understand why evacuation modeling complements site accessibility, one must analyze city planning. Every United States city has an evacuation plan in place. While every city addresses the issue of planning differently, Philadelphia Pennsylvania is the example that will be utilized in this application. Pennsylvania's evacuation plan for the city is divided up into Central, East, Northeast, Northwest, South and Southwest areas and then further divided by evacuation zone. Within each zone, a detailed map of the evacuation routes specific to the zone number, includes main streets for: pedestrians and mass transit, pedestrians and all vehicles, pedestrians only, private vehicles, bus, tram, trolley, subway or streetcar axcess figure 17.[31]

[31] Ibid.

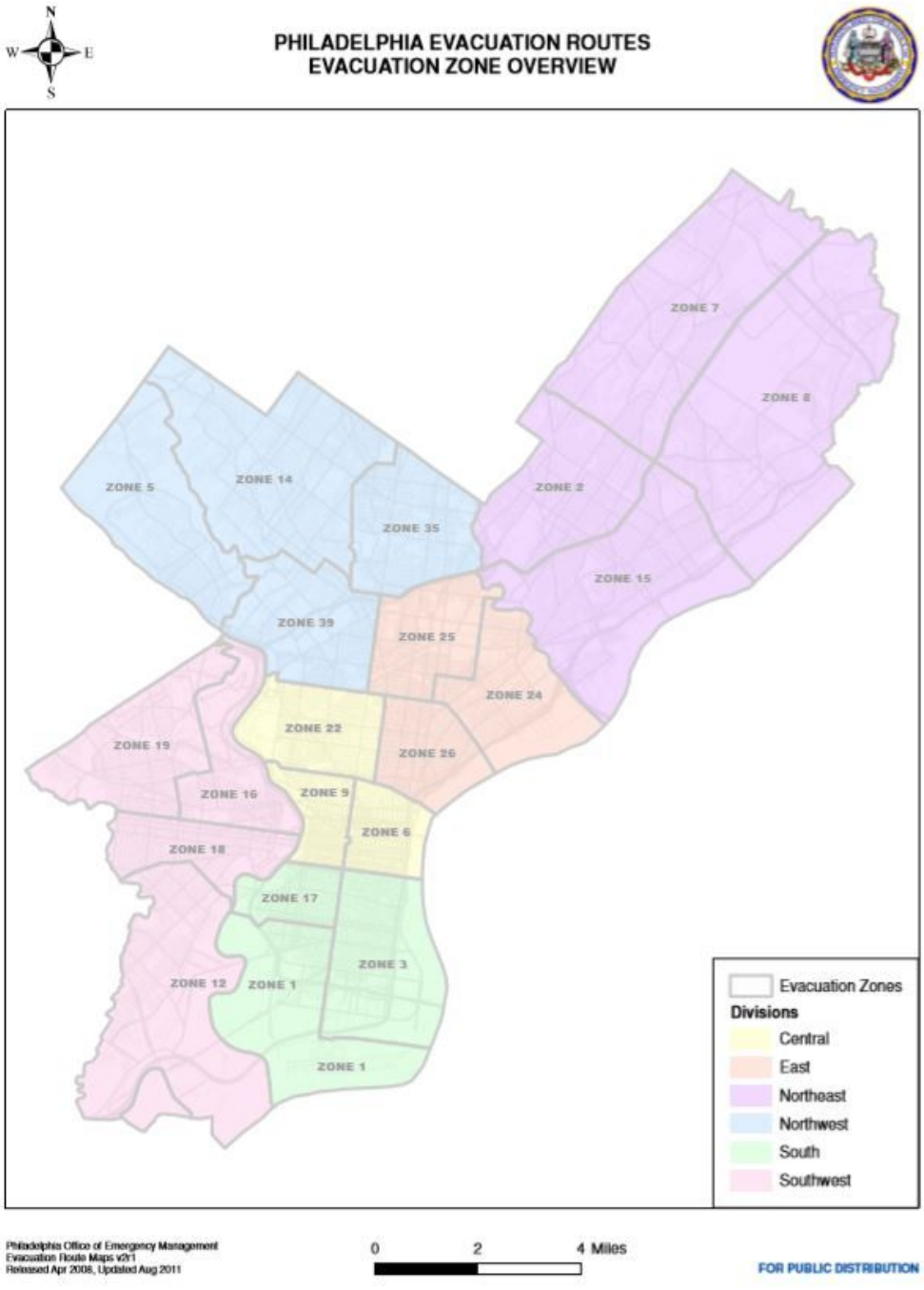


Figure 17 U.S. Department of Commerce Philadelphia Evacuation Zones

There are multiple factors that contribute to site accessibility. Often times highways have to be opened up in order to let more people out of the area, to minimize congestion. Geographic barriers such as bodies of water, mountain ranges, etc. Population density, traffic congestion within the city especially at narrow areas of the road; all of these factors and more influence said person's ability to access a site in an emergency situation[32]. In order to choose the best location, within a city at risk it is crucial that the existing building is accessible in all of the ways described above.

At the onset of a natural disaster precautions are taken to evacuate several days before the storm is predicted to hit land. With such a short evacuation time it is imperative that the proposed facility be accessible to the public by multiple forms of transportation. Depending on the city, each will have its own designated evacuation routes in order to maximize the number of people leaving the at-risk areas. Those who are able to get to the facility, must have parking available to them. Those who cannot get to the facility by car, must have access directly to the location by public transit. For those who are taking public transit to the proposed facility bus services end several hours before the wind speed reaches 39 mph[33]. This is a very small window of time, adding in the additional time accrued from traffic congestion; often as numerous people attempt to evacuate at the same time. As the storm intensifies the National Hurricane Center or the NHC will issue a warning if winds have been constant at 74 mph or greater. This is followed by a 36

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[32] "The Best and Worst Cities to Evacuate During a Disaster." Envista Forensics. Accessed May 10, 2019. https://www.envistaforensics.com/blog/the-best-and-worst-cities-to-evacuate-during-a-disaster/

[33] "Move Forward – In-depth International Coverage of Future Trends in Mobility." Move Forward – In-depth International Coverage of Future Trends in Mobility. Accessed May 10, 2019. https://www.move-forward.com/public-transit-use-for-disaster-recovery/.

hour hurricane warning for evacuation[34]. During this time all public transit will be shut down and people are only able to evaluate if help is sent to them or if they have a personal means of leaving the area. Designating a facility that is close enough to those who will need to evacuate is a probable way to create accessibility in times of emergency.

[34] US Department of Commerce, and Noaa. "Hurricane and Tropical Storm Watches, Warnings, Advisories and Outlooks." National Weather Service. March 28, 2019. Accessed May 10, 2019. https://www.weather.gov/safety/hurricane-ww.

2.1.4 Structural Integrity

Building selected must show proof of adequately meeting the needs of the disaster per region. As can be seen in figure 18 which illustrates the boundary for the Hurricane-flood prone regions which require additional roof tie downs to accommodate extreme wind conditions[35].

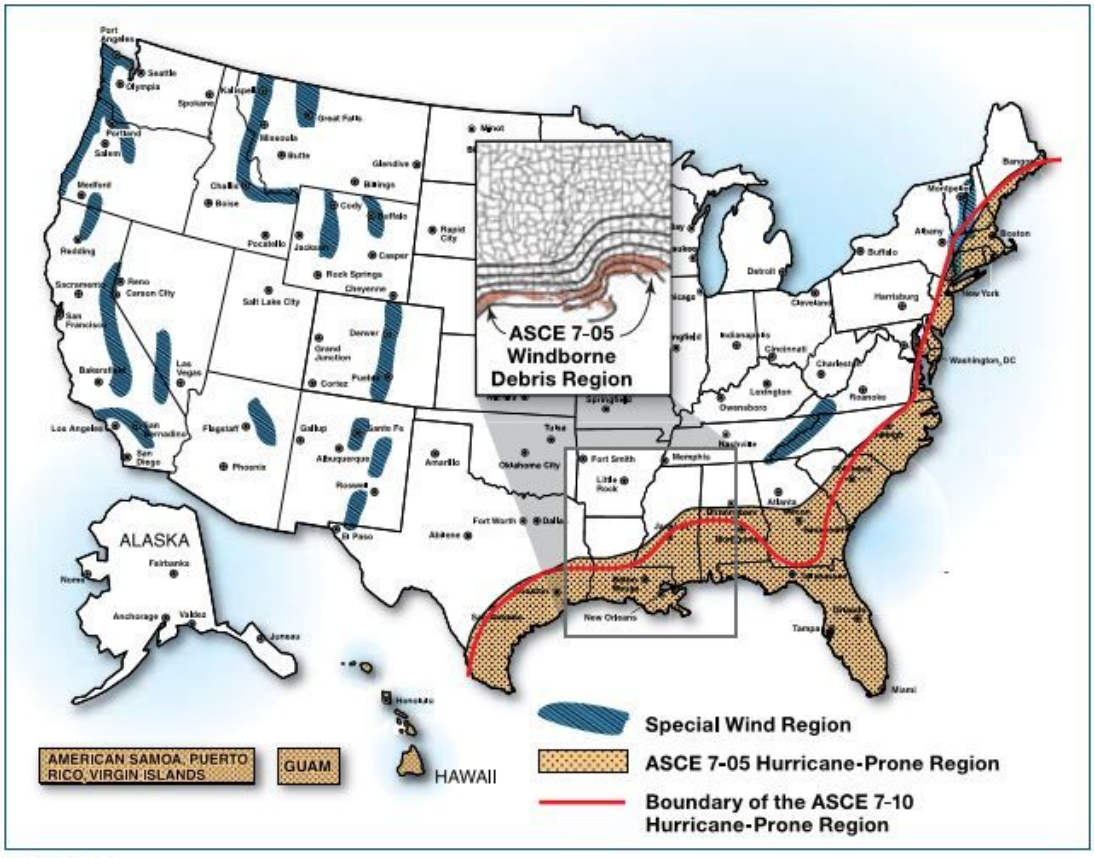

Figure 18 FEMA Illustration of Hurricane-prone regions United States

Since, this research focuses on retrofitting for existing large scale facilities, rather than designing new builds located in hurricane and flood prone regions; the structural integrity of the facility is of the utmost importance. When looking at possible stadiums or convention centers several questions must be answered. When was it built? What materials were used? Are the materials

[35] United States of America. FEMA. *Wind Retrofit Guide for Residential Buildings*. 1-115. Accessed 2019. https://www.wbdg.org/FFC/DHS/fema_p_804.pdf.

durable? Answering these questions will be a quick way to “weed” out buildings that may meet the large occupancy, and site accessibility criterium but are built from materials that are not going to hold up structurally. So, what should a building have to be considered? Concrete, more specifically steel reinforced concrete which is engineered to withstand strong winds figure 21.

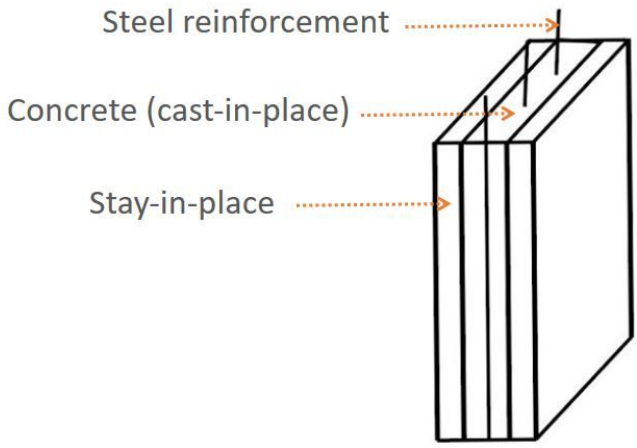

Figure 19

Another feature of concrete material is that it does not weaken when in contact with water. Unlike wood, concrete provides a suitable option for two of the components needed in the conditions that are being created and analysed. Due to high wind conditions, any glazing or glass must be high impact which is comprised of 2 layers of glass with a plastic interlayer and will look like figure 20.

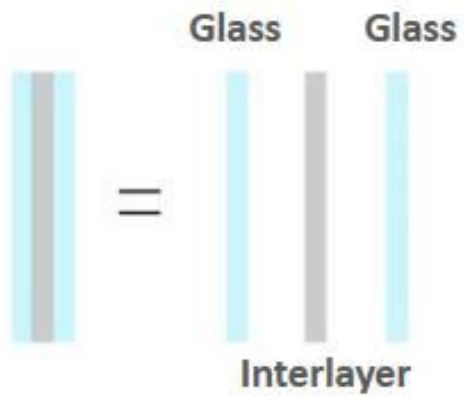

Figure 20

Moreover, windows that fail can compromise the whole of the building envelope, which can then lead to the roof blowing off. This also returns to the importance of making sure that the roof is tied down to the foundation, in figure 21 FEMA depicts this showing how that windlift can be reduced[36]. While this is a wood-framed building the concept still applies as the behavior of wind pressure does not change while the material may differ.

[36] United States of America. FEMA. *Wind Retrofit Guide for Residential Buildings*. 1-115. Accessed 2019. https://www.wbdg.org/FFC/DHS/fema_p_804.pdf.

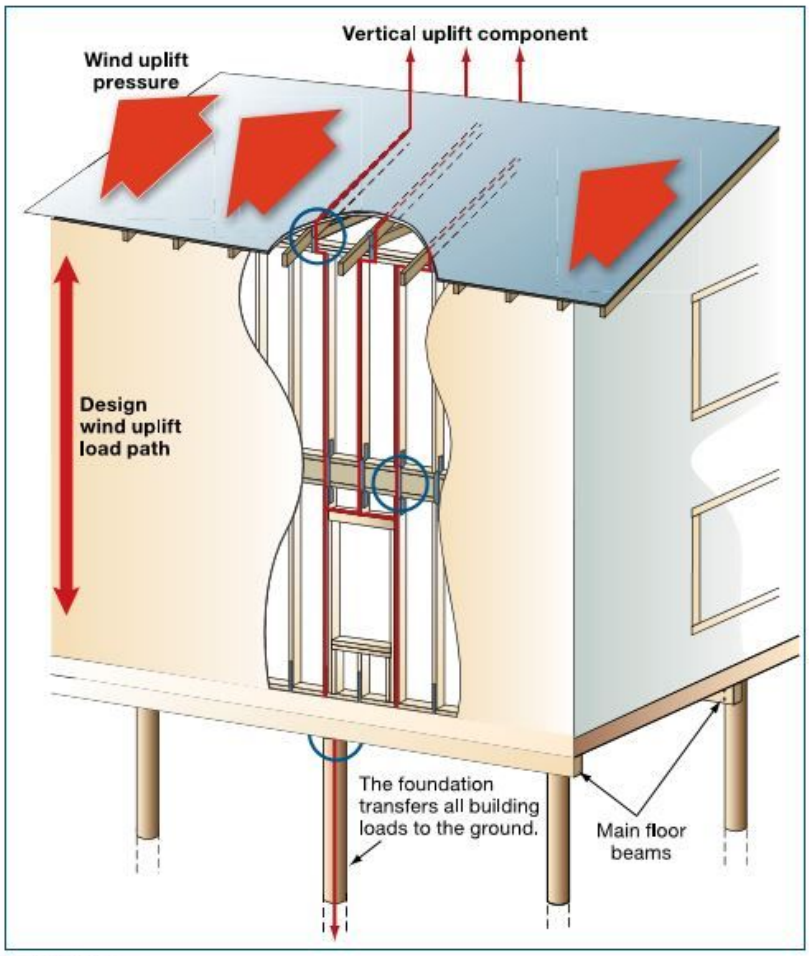

Figure 21 FEMA load path diagram

Materials that make up the surrounding walls of the mechanical rooms must be fire resistant as well, since equipment upon shut off may spark causing potential for fires.

2.1.5 Large Occupancy

In order to accommodate for a significant area impacted the building must be large enough to adequately reflect the at-risk city. The said facility needs to have enough square

footage to service a large number of occupants for an extensive duration of time. Reflecting on past disaster relief facilities this was anywhere from 5 days to 58 days like the Cajundome. The Cajundome is at maximum capacity at 11,500 however; during hurricane Katrina the Cajundome was able to receive roughly 18,000 occupants[37]. The city population in the table below courtesy of the U.S. Census Bureau figure 22[38].

Building location	Structure name and type	Expected Occupancy	Occupancy during Natural disaster	Days as shelter	Population of City
Lafayette, LA	Cajundome	11,500	18,000	58	111,726
New Orleans, LA	Superdome	71,000	15,000-20,000	5	454,845

Figure 22

When natural disasters strike especially hurricanes and floods, often the area impacted extends over a significant portion of the state experiencing said disaster. This is why implementing a handful of stadiums or large scale public facilities like convention centers divided by region within the state would provide an effective option as one would not be sufficient for the tens of thousands in need. Stadiums and convention centers on average can house anywhere from 7,000-100,000 people roughly[39]. When selecting a building it is important to consider that the maximum occupancy restriction for buildings during natural disasters can be slightly higher that the designated number.

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[37] Lavigne, Lora. "Remembering the Cajundome Mega-Shelter during 13th Anniversary of Hurricane Katrina." KLFY. August 29, 2018. Accessed May 10, 2019. https://www.klfy.com/news/local/remembering-the-cajundome-mega-shelter-during-13th-anniversary-of-hurricane-katrina/1401469839.

[38] "U.S. Census Bureau QuickFacts: New Orleans City, Louisiana." Census Bureau QuickFacts. Accessed May 10, 2019. https://www.census.gov/quickfacts/neworleanscitylouisiana.

[39] "List of U.S. Stadiums by Capacity." Wikipedia. May 05, 2019. Accessed May 10, 2019. https://en.wikipedia.org/wiki/List_of_U.S._stadiums_by_capacity.

2.1.6 Staging & Storage

In order to accommodate for a significant area impacted to proposed building needs to have allocated storage for disaster kits and/or have a designated storage near the site. Less than 1 mile. See figure 23..

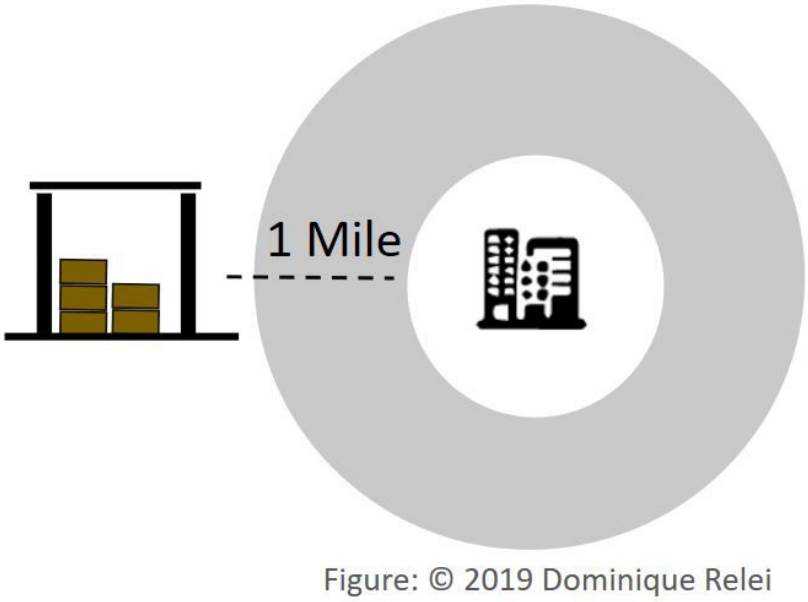

Figure 23

While Part one of preparedness for the facility is external and is done months prior to a potential disaster, the second part of the preparedness phase deals with preparation of the allocated spaces in accordance with the set program of the building; that are to be executed with momentary notice. Therefore, while many items can be brought into the space when there is a need for additional supplies; the majority of emergency supplies needed will be stored in a designated area on site. The square footage for the allocated storage space is reflective of the usable space as well as the projected amount of occupants seeking shelter. Since the designated facility is allocating space for disaster relief efforts, it is possible for some materials to be

displayed in order to educate the public on a day-to-day basis. This display would act as an art installation-yet would be secured and ready for immediate use. A small portion of items would be displayed while a majority of them are to be locked in a area on site. As previously referenced in Hurricane Katrina-one of the main reasons that they could not meet the needs of those who came to the site were not because they were unorganized in their ability to get supplies to site. In learning from this, the proposed building would need permanent storage designated space.

2.2 Building Programming

Considers pedestrian flow to and within the building prior to and during a natural disaster. During times of panic occupant safety is of the utmost importance. As well as re-establishing a sense of wellbeing through the implementation of spaces that can be quickly assembled and disassembled for future use. Within building programming there are seven subcategories which are: accessibility/emergency, security and safety, space type, circulation, module systems, flexibility.

2.2.1 Accessibility/Emergency

Inside the facility emergency wayfinding paths must be implemented along designated egress. In the conditions addressed, momentary power outages may occur, which is why this methodology seeks to apply FEMA's emergency wayfinding tool which are photoluminescent strips made from a material that is charged by lighting when lighting is shut off the charged material then glows to aid in illuminating exits for evacuation purposes figure 24.

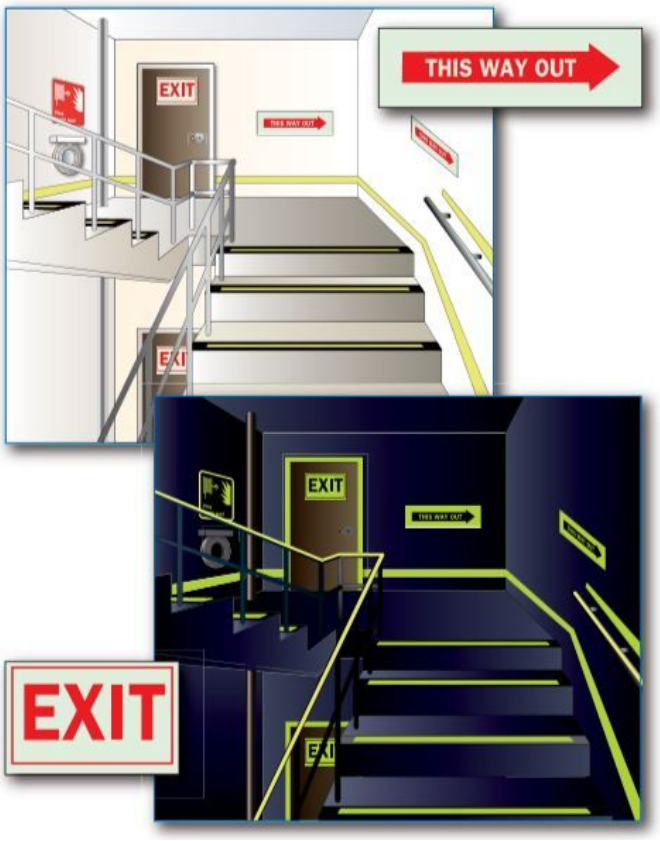

Figure 24 FEMA Photoluminescent signs, route marking

The second part of the program for accessibility and emergency is to have a building management team that is trained and always up to date on procedures and can be replaced and trained as needed[40].

[40] "Emergency Management Considerations." Accessed May 2019. https://www.fema.gov/media-library-data/20130726-1523-20490-0615/fema453_ch4.pdf

2.2.2 Security/Safety

Security check-points prior to registration upon entrance into the facility ensure safety for all occupants. Natural disasters affect the physical and psychological state of those involved[41]. According to BioMed Central in a work on *Post-traumatic stress disorder, depression and generalised anxiety disorder in adolescents after a natural disaster: a study of comorbidity*, Those affected one year after a cyclone hit India, "prolonged periods of helpless and lack of adequate post-disaster psychological support...as well as the severity of the disaster," were directly connected to PTSD, anxiety, and signs of depression in the students that were in the affected area[42]. During times of crisis it is important to re-establish a sense of security and safety as well as a sense of normalcy. The Inter-Agency Standing Committee or the IASC, that works in coordination with the United Nations and non--UN humanitarian efforts has developed several Operational Guidelines for those experiencing a disaster. Including but not limited to "rights related to physical security and integrity, rights related to basic necessities of life, rights related to other economic, social, and cultural protection, and rights related to other civil and political protection.[43]" The first two listed would be demonstrated immediately. Making sure that there is protection from assault, robbery of any kind etc; as well as, axcess to clean water, shelter and

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[41]Nilamadhab Kar, and Binaya Kumar Bastia. "Post-traumatic Stress Disorder, Depression and Generalised Anxiety Disorder in Adolescents after a Natural Disaster: A Study of Comorbidity." Clinical Practice and Epidemiology in Mental Health. July 26, 2006. Accessed May 10, 2019. https://cpementalhealth.biomedcentral.com/articles/10.1186/1745-0179-2-17.

[42] Inbid.

[43] Ferris, Elizabeth."Natural Disasters, Human Rights, and the Role of National Human Rights Institutions." Brookings. July 29, 2016. Accessed May 10, 2019. https://www.brookings.edu/on-the-record/natural-disasters-human-rights-and-the-role-of-national-human-rights-institutions/.

basic necessities. Taking inspiration from their efforts, in order to create a space that is secure while providing the above certain precautions must be implemented. When the United States is on the verge of a natural disaster, it is the local government that responds first and activates the Emergency Operations Center and the Emergency Operations plan, which then coordinate with other relief organizations. Local authorities are able to aid with evacuation and directing people to a secured area. Once a local state of emergency is declared, assistance is then requested from the State. Who reviews the situation, determines its severity and requests aid on a federal level. Once preliminary damage assessments are made with state and local governments the federal government will then approve or deny assistance. If approved will begin a Federal Response Plan, Emergency support team, and Emergency support functions that coordinate with FEMA to aid in the support of those involved.[44] While there are many factors to take into consideration for the proposed facility and surrounding site; the program of the allocated space is what this section focuses on. More importantly, how people in evacuation zones are entering and exiting the facility. In order to minimize chaos and provide a truly safe space, implementing security checkpoints at the allocated entrances and exits of the space. With security metal detectors inside the proposed facility is a plausible way to insure the safety of those inside the space; as is the standard for anything from entrance into various educational institutions as well as is implemented at a variety of events which are open to the public. Upon passing through security people are welcome to partake in the many amenities provided for them. This concept is similar to what one would go through when entering an airport, and can be seen in Transportation

[44] *Unit 3 Disaster Sequence of Events*.
https://training.fema.gov/emiweb/downloads/is208sdmunit3.pdf

Security Administration or TSA's Security Administration Checkpoint Design Guide Diagram in figure 25 below.[45]

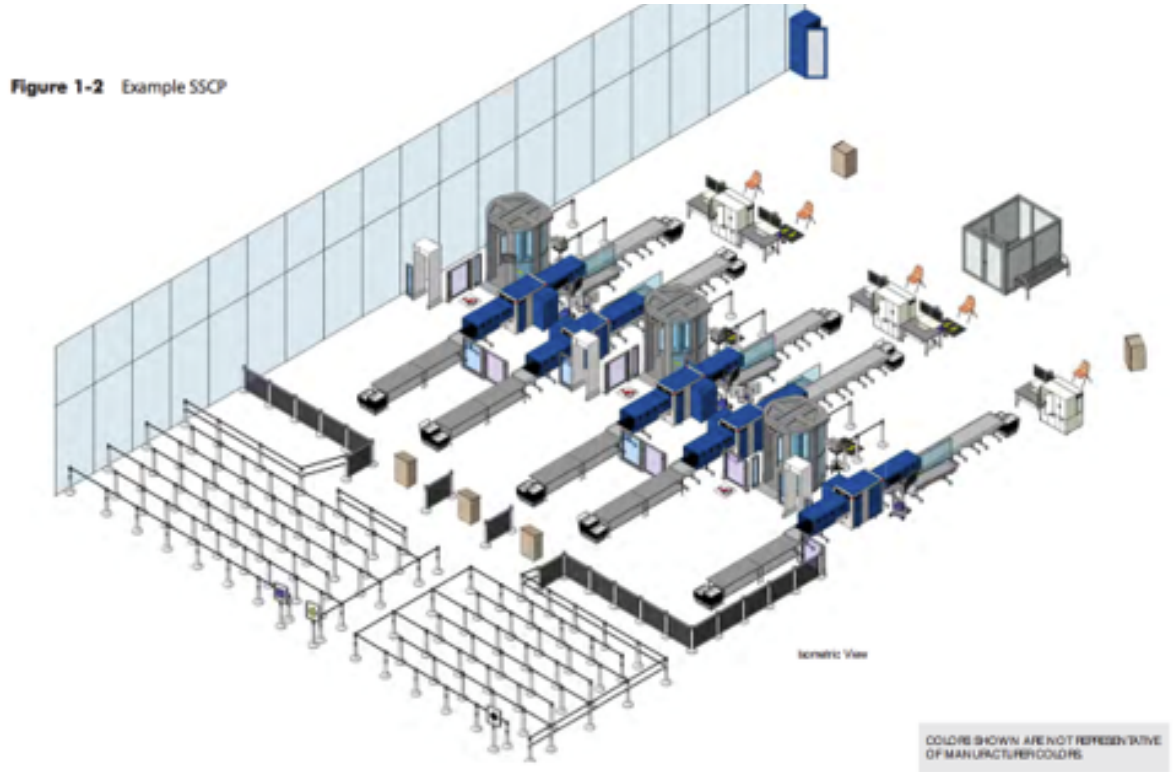


Figure 25 TSA Diagram

2.2.3 Space type

In reference to the case studies and research conducted, spaces have been established which consider: clinics for those in need of medical assistance, eatery, designated private sleeping areas with privacy, and access to an area which provides news and weather updates so evacuees can be informed. In order to create a holistic space that is functional and meets the needs of those during a natural disaster, the many individual spaces that make up the whole

[45] United States. Transportation Security Administration. TSA. *Checkpoint Design Guide*. 1-162. http://files.constantcontact.com/8c363cd8001/f070043f-495f-42bf-99b4-d1688c57e199.pdf

mechanism must be defined.Sleeping quarters. Past case studies have attested to the terrible conditions that people from all walks of life find themselves in when a natural disaster occurs. The right to privacy is replaced by the need for safety, and along with it goes any sense of normalcy or decency. It is possible to house people in a humane way, by planning in advance their sleeping arrangements. This can be done through the implementation of operable and transformable spaces, which can house individuals as well as families, or groups of singles. The proposed mechanisms can serve a variety of purposes, from sleeping quarters, to temporary dividing walls, to small clinic rooms. Pharmacy, the proposed area will have extra supplies needed such as first aid kits, baby kits, it will also serve as a pick up area for medical prescriptions. Clinic and hospital, will be located near a large exit which is accessible and designated for ambulance use. The clinic and hospital serviced by nurses and doctors who provide assistance to those in physical need. No large scale surgeries will be performed. A helicopter pad is available if patients are in a state of need beyond what the relief shelter can provide. Supply room/storage. Where extra supplies are kept for the pharmacy, sleeping quarters, eatery.etc. Backup power. Room designated for the backup generator, and future use of alternative energy.

2.2.4 Circulation

Leading up to a natural disaster, there can be panic and confusion. In order to reduce this, clearly marked entrances on site leading up to the main entrance as well as allocated emergency exits are mandatory. Occupants will be given a map of the facility, which is a simplified plan with emergency exits and amenity areas. Figure 26 see example for shelter marking floor plan with exterior exits from FEMA[46].

[46] "Emergency Management Considerations." Accessed May 2019. https://www.fema.gov/media-library-data/20130726-1523-20490-0615/fema453_ch4.pdf

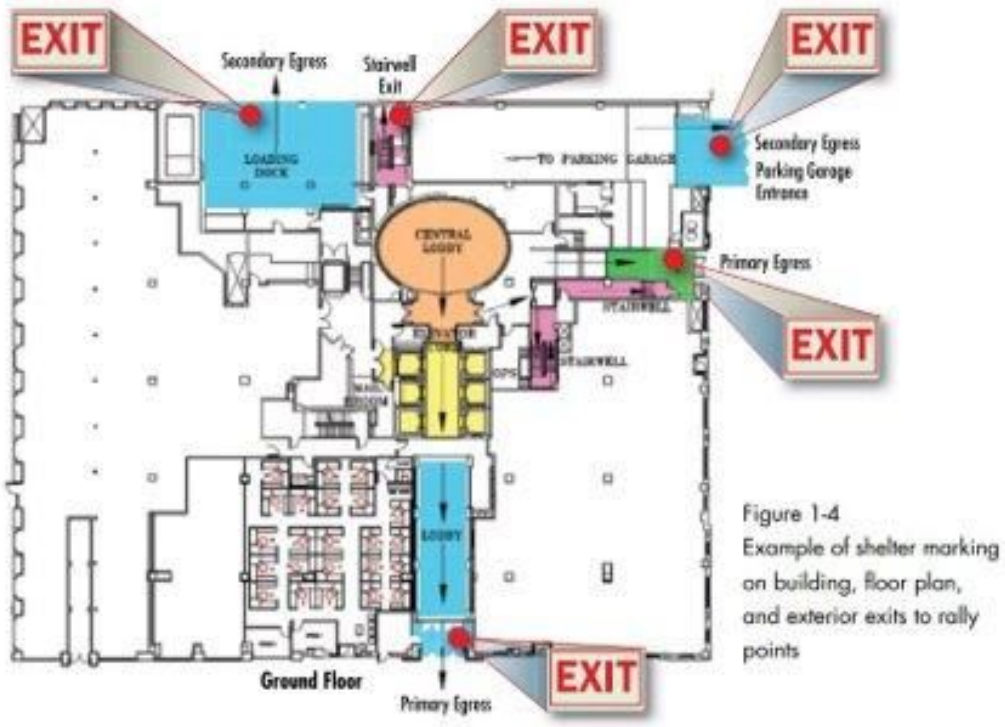


Figure 26 FEMA

2.2.5 Module Systems

In order for the proposed facility to be considered for renovation it must undergo a process to be implemented in two phases. Phase 1 or the pre-preparedness phase. Where the facility is prepped externally and internally. This phase pertains to the building envelope and includes: wet floodproofing, dry floodproofing, and roof tie down and wind speed compliance for hurricane zones figures 40-45. Implementing wind turbines, in order to utilize wind power as a renewable energy source. Phase 2 involves the action phase this phase is to be implemented when disaster is coming and a few days or possibly a week has been given to prepare. In this time, the internal program of the facility will be designated per function and need. This includes, the implementation of fabric curtain walls to create divisions of spaces for occupants.

In order to accommodate for growth and to create a sense of community spaces the design for the division of space allocated for the sleeping quarters is both flexible and quickly transformable. Temporary rooms are created that sleep a family or group of 4 bunk beds. There are 3 static panels 8’ x 8’and a 5’ x 6’4” panel for the entry. The door openings 6’ 4” x 3’ have curtain rods with outdoor fabric material serve as a door for entry and exit figure 27.

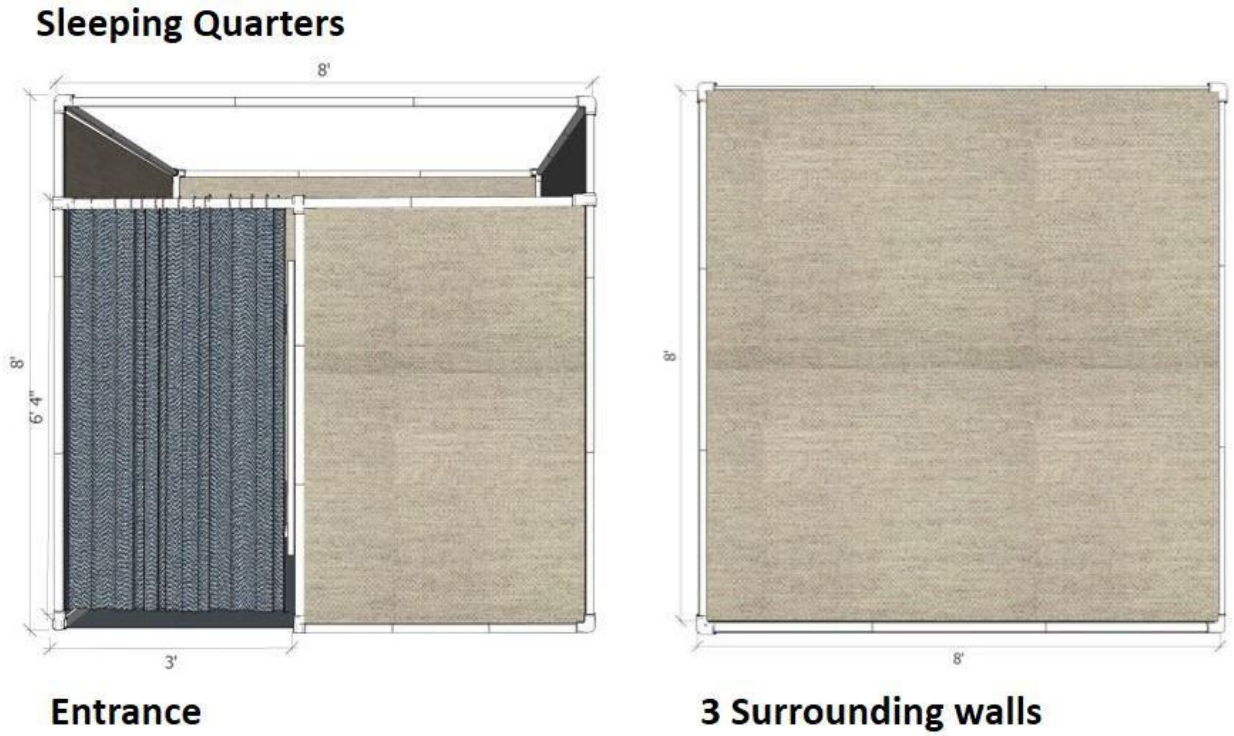


Figure 27 © Dominique Relei

For a smaller group of 1-2 singles or couples the second module option is 2 side static fabric panels with PVC and fittings at 8’ x 8’, one back wall at 8’x5’ and a front entry with outdoor curtain for privacy at 6’ 4” x 5’. Space for 1 bunk bed, figure 30.

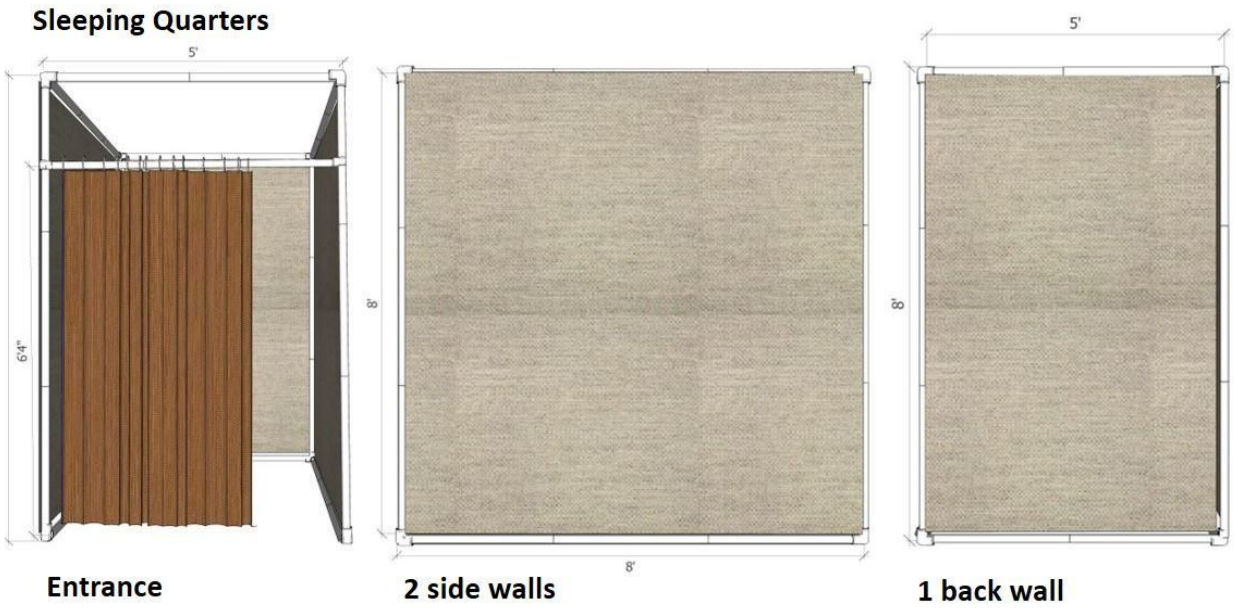


Figure 28 © Dominique Relei

To serve as a clinic space, with soothing colors 3 panels are composed of 8’ x 8’ attached canvas and 14, 2” PVC pipes with 10 fittings. The privacy curtain made from outdoor fabric hangs on a 2” PVC making a wide entry for patient beds/nurse staff figure 28.

Figure 29 © Dominique Relei

In order to create temporary divisions of space, these parti-walls are multi-purpose and can serve a variety of functions. 3, 8’ x 5’ panels are composed of 12 PVC 6, 8 pipes and 6, 5’ pipes and 12 pipe fittings. See figure 29.

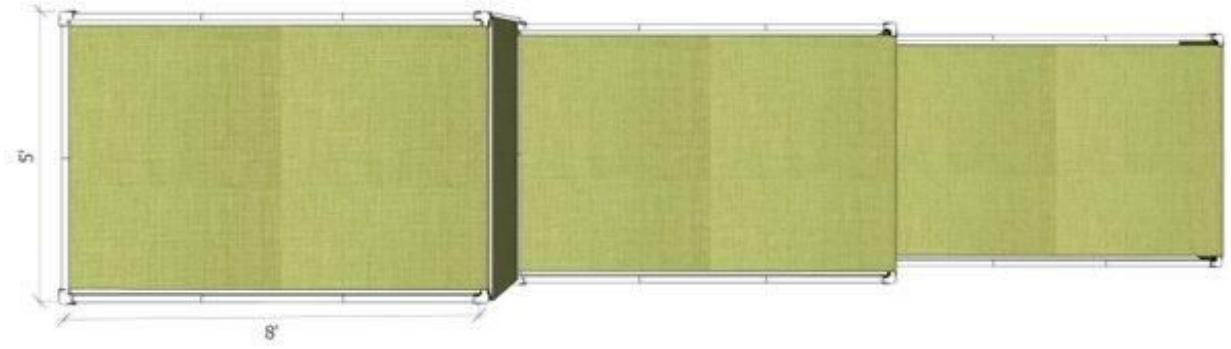


Figure 30 © Dominique Relei

To serve as a separate area for pets or for other uses this module system is comprised of 12, 6’ x 8’ panels, 24, 2” PVC pipes with 24 pipe fittings see figure 31 below.

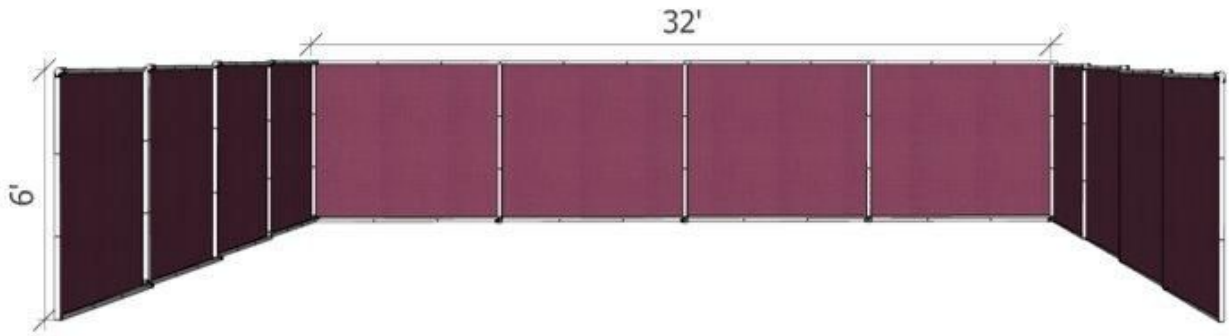


Figure 32 © Dominique Relei

2.2.6 Flexibility

When programming a space which serves as a disaster relief center it is important to consider whether the chosen facility provides enough flexibility to meet the programmatic needs. Which is why, analyzing the benefits of an open floor plan versus a closed floor plan further supports the importance of choosing the correct building type. Figure 33 depicts an example of an open floor plan and closed floor plan. What can be seen from the open floor plan is the large spaces, with minimal to no parti-walls or smaller rooms, leaving more square footage to be allocated to a variety of space types be it a clinic, eatery, or sleeping quarters. In contrast with an enclosed floor plan which has many parti walls and spatial divisions. This makes it challenging

for the spaces to be allocated for a variety of uses. For this methodology an open floor plan which allows for that flexibility and the program can dictate the function of the space.

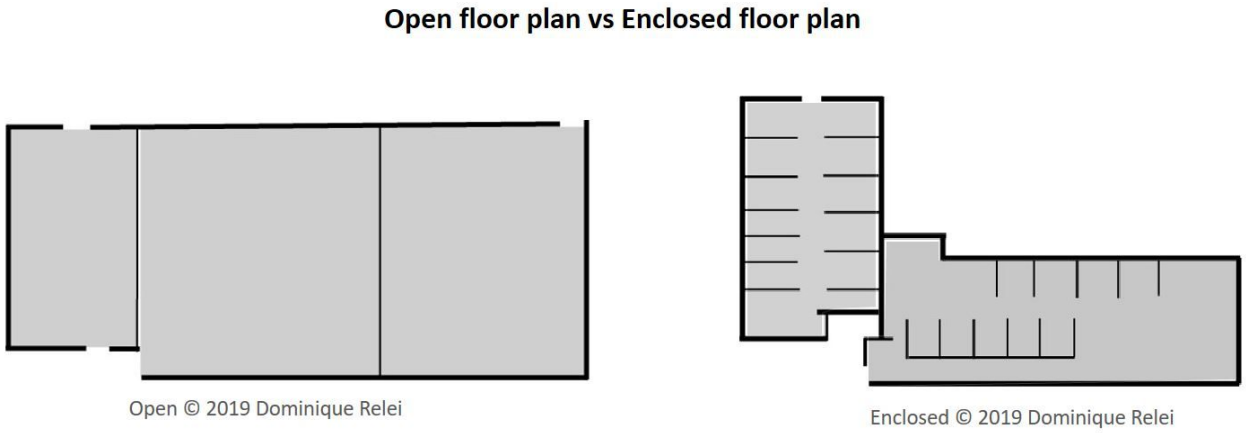


Figure 33 Comparison

2.2.7 Scheduling/Response

As natural disasters occur suddenly, the minimum amount of time given to prepare facilities for hurricanes are 34 hours, while the maximum amount of time can be about a week out. This is why preparation must be far enough in advance to address issues involving security of the building envelope as well as site selection which has been broken down in detail under 2.1 building identification including: building type, building location, site accessibility, structural integrity, large occupancy, and staging and storage. In terms of programming the space, establishing the registration, and security areas on the main level are to be executed first

followed by restricting areas that are are not to be used. The next area to be addressed is setting up the modules previously discussed for sleeping quarters, bringing in additional restrooms and showers, clinic modules, eatery space set up, and establishing a room for weather updates and announcements as can be seen in figure 34 below.

1	2
Registration	Sleeping Quarters
Security	Restrooms/showers
Block of restricted areas	Clinic
	Eatery
	Weather update/announcements

Minimum 34 hours

Figure 34

2.2.8 Lessons learned

Not every disaster is going to be the same-there will always be room for improvement. As this process is implemented the program will need to be adaptable, and have room for implementation of more efficient concepts to accommodate those in need. Therefore, this methodology allows for future growth in all areas.

3.0 Application of Methods Philadelphia Convention Center

3.1 Building Identification

To test the first component of my methodology, I will now explain the application and process of identifying the Pennsylvania Convention Center. Beginning with building identification, with it's 6 categories that include: building type, building location, site accessibility, structural integrity, large occupancy, and staging and storage.

3.1.1 Building Type

When selecting the building type that could best serve as a center for disaster relief, one must look at the pros and cons of various building types. To put this in a realistic context 2 building types in Philadelphia Pennsylvania were chosen to see if they would meet the discussed criterium for building selection see figure 35.

Hospital	Hotel	Convention Center
Chesnut Hill Hospital in Philadelphia is over a ½ hour away from the center of the city by public transit, 1 hour by bike. Mult-irise.	The Morris House hotel is in the center of the city and is axcessible through multiple points of axcess. However the age of the building would not adequately perform.	Pennsylvania Convention Center is a win for 2.1.5 large occupancy, 2.1.structural integrity, and access.
Access	Structural Integrity	Large Occupancy

Figure 35

Chestnut Hill Hospital located in Philadelphia, Pennsylvania is over a ½ hour away from City Center which is the area of the city that is addressed in this research by public transit, 1 hour by

bike, and 45 minutes by car. Unfortunately this is too far in order for it to meet the discussed criterium for building access see figure 36.

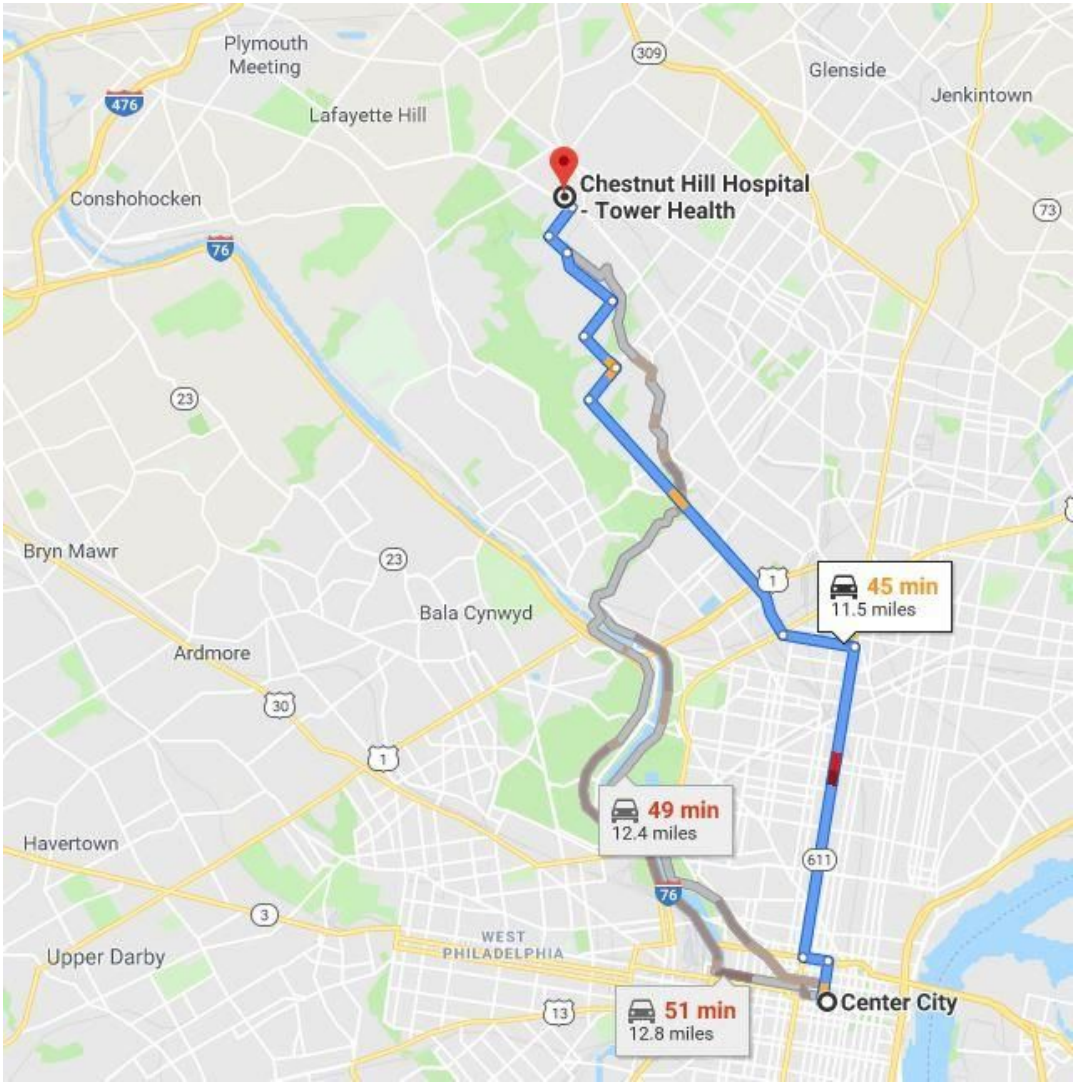


Figure 36 Google maps Image of Distance Chestnut Hill Hospital & City Center

The Morris House Hotel, while it is located in the City Center and is a prime location that is accessible by public transit as well as by other forms of transportation. However the hotel is on the historical registry and is over a hundred years old, with little renovation done to the original structure itself making it structurally compromised. Therefore, it does not comply with the established methodology as can be seen in figures 37 entrance and 39 the back of the facility.

Figure 37 Morris House Hotel © Dominique Relei

Figure 38 Morris House Hotel © Dominique Relei

The Pennsylvania Convention Center in Philadelphia however, has optimal access as can be seen by figure 39 which shows the multiple forms of transportation to the site; as well as, has structural integrity as discussed in 3.1.4 Structural Integrity as can be seen from the recent expansion and renovation in 2011. Which in turn added additional square footage for increased occupancy to 45,522[47].

[47] Convention, PA. "Capacity Charts." PA Convention. 2019. Accessed May 10, 2019. https://www.paconvention.com/meeting-professionals/floor-plans.

3.1.2 Building Location

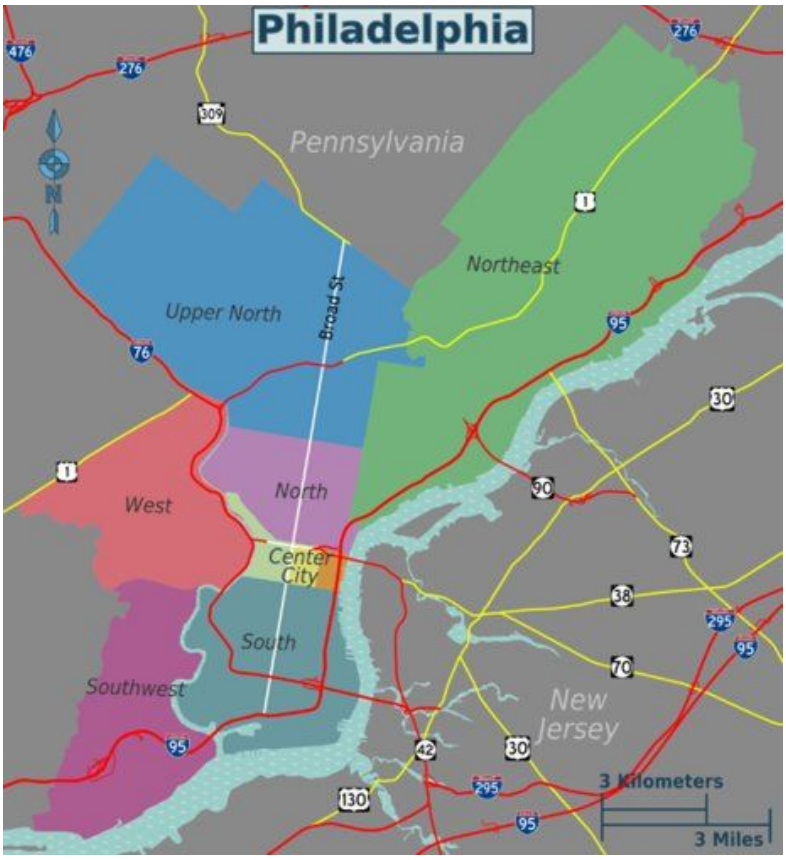


Figure 39 Philadelphia Districts Map[48]

The city of Philadelphia is located in the Southeastern tip of the state of Pennsylvania at 39.95 degrees North latitude and -75.16 degrees West longitude. Philadelphia is located at 31' above sea level, with annual temperatures ranging from an average high of 89 degrees Fahrenheit in July to an average low of 28 degrees Fahrenheit in January[49]. The city has a population of approximately 1.58 million and is also among the top ten most densely populated

[48] "Philadelphia Districts Map." Digital image. June 2009. Accessed May 2019. https://commons.wikimedia.org/wiki/File:Philadelphia_districts_map.png

[49] National Centers for Environmental Information, and Ncei. "Daily Summaries Station Details." Daily Summaries Station Details: PHILADELPHIA INTERNATIONAL AIRPORT, PA US, GHCND:USW00013739 | Climate Data Online (CDO) | National Climatic Data Center (NCDC). Accessed May 10, 2019. https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00013739/detail.

cities for the United States; and the fifth largest city in persons/sq. mile on the East coast[50]. The Philadelphia Convention Center is located in the City Center district of the state directly between the Schuykill River and the Delaware River and can be seen in the Philadelphia Districts Map [51]. It's central location means that it is also considered to be out of the flood and storm surge zones. According to the FEMA Flood Map Center and the Department of Homeland Security the Pennsylvania Convention Center is located in an area of minimal flood hazard and can be seen marked by the red symbol showing the geographic location in figure 40 below[52].

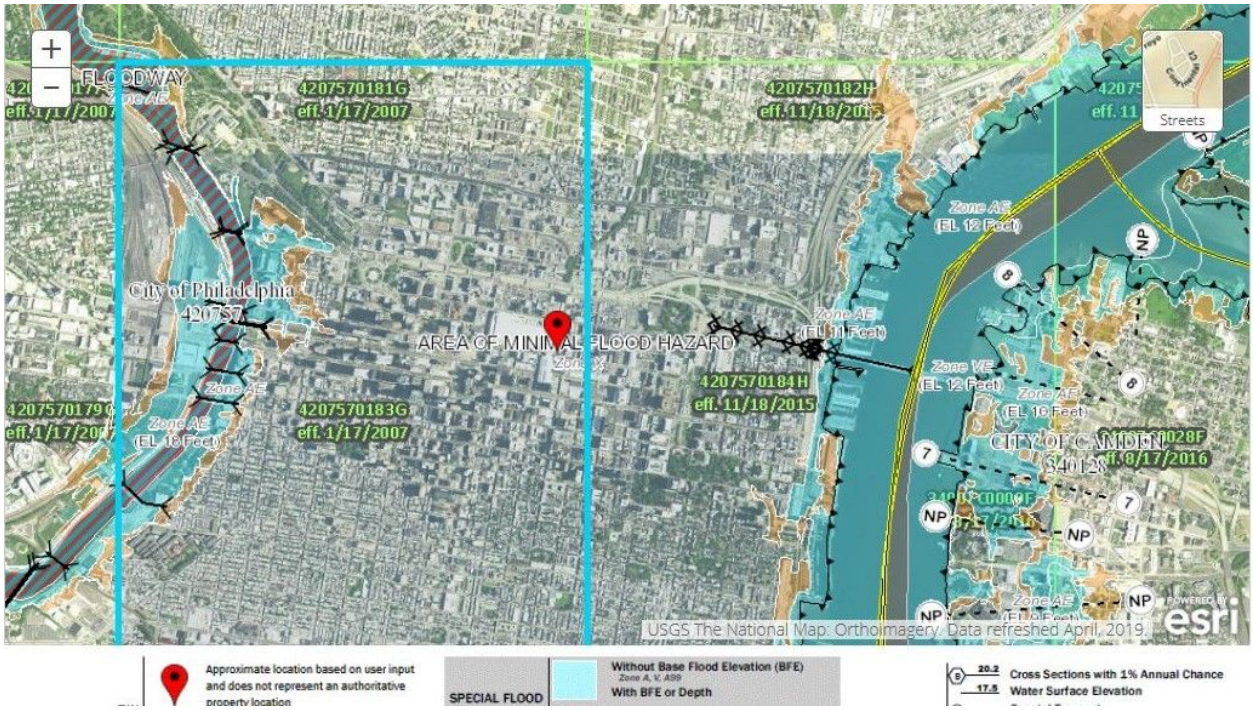
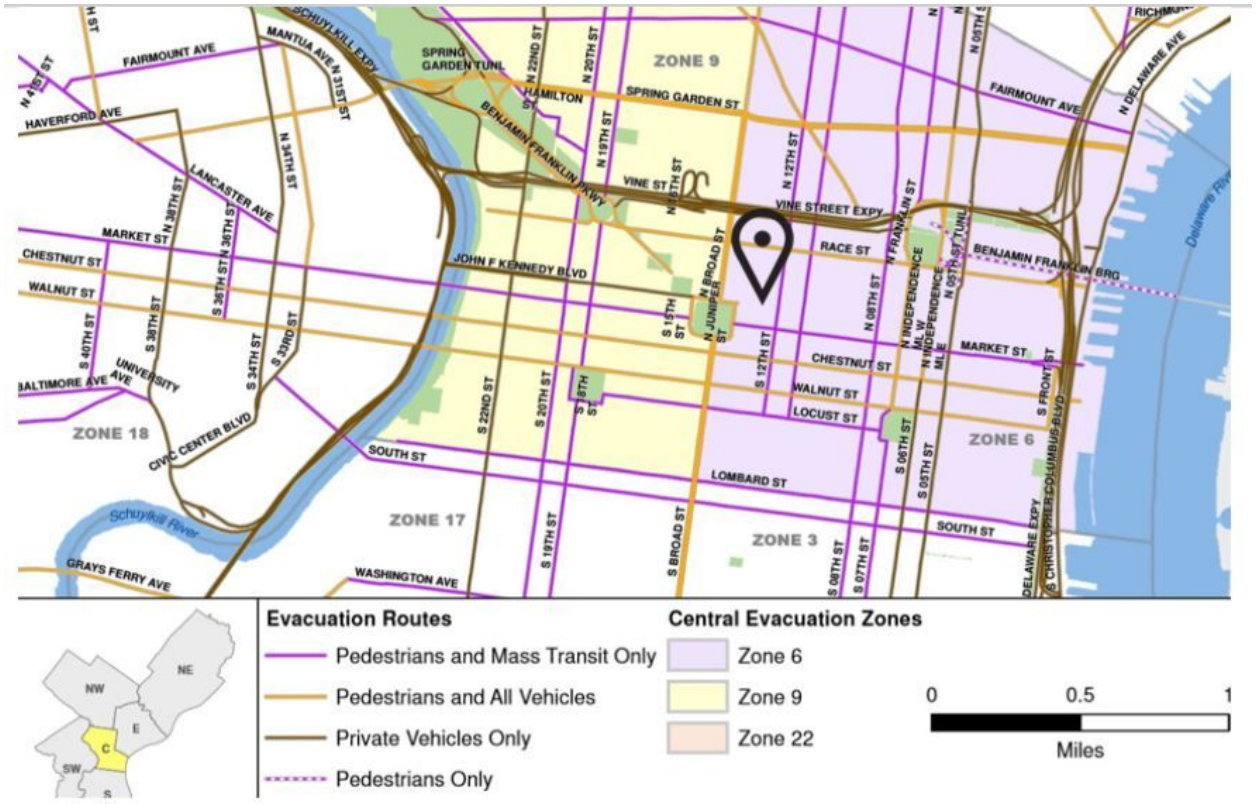


Figure 40 Pennsylvania Convention Center Floodplain Map

[50] "Population Density for U.S. Cities Statistics." Governing. Accessed May 10, 2019. http://www.governing.com/gov-data/population-density-land-area-cities-map.html.
[51] "Philadelphia Districts Map." Digital image. June 2009. Accessed May 2019. https://commons.wikimedia.org/wiki/File:Philadelphia_districts_map.png
[52] "FEMA Flood Map Service Center: Search By Address." View/Print FIRM: View an Image of the FIRM Panel or Print a FIRMette for Your Chosen Location. NOTE: This Is a Static Map and Has Not Been Updated since the Effective Date. Please Refer to Any Amendments or Revisions (LOMC) in the Changes to This FIRM Section. Accessed May 10, 2019. https://msc.fema.gov/portal/search#searchresultsanchor.

3.1.3 Site Accessibility

The site is accessible to major traffic flow coming from 12th and 13th street as the Convention center is connected on the 2nd level in these areas figure 41. Which allow for buses, and public transport to pass through; as well as, bikes and cars. It is also accessible to Broad and Arch street along the East and West facade. There are multiple points of entry to the facility, as well as exits and a large ramp for loading onto the second level along the North facade[53].



Source: City of Philadelphia Evacuation Routes

Figure 41

[53] Nutter, Michael, Everett Gibson, and Liam O'Keefe. "Evacuation Routes Map." *Evacuation Routes*, August 2011, 1-30. Accessed 2019.

There is a nearby hospital if needs arise that cannot be met at the clinic set up described later in the program. Public transit so close to the structure means that people who don't have a car or are too far away to walk can reach safety during the warning signs of disaster figure 42.

Figure 42 Public Transit Route

Bike routes go right through the site as well in figure 43.

Figure 43 Bike route

Of course vehicles have multiple forms of entry to the site by the main interstate highway 676 and Race, Arch, 13th and 12th streets figure 44.

Figure 44 Car Access

3.1.4 Structural Integrity

Philadelphia Convention center in 2011 incorporated cast in place waffle slab concrete, and steel create a structural frame that support the added trusses.Brick, granite, limestone, also makeup the building components. On the construction steel reinforced concrete is used for this facility, as well as truss framing for the ceiling.[54]According to the above research this is one of the many recommended approaches to structural integrity for buildings experiencing high wind conditions figure 45 and 46.

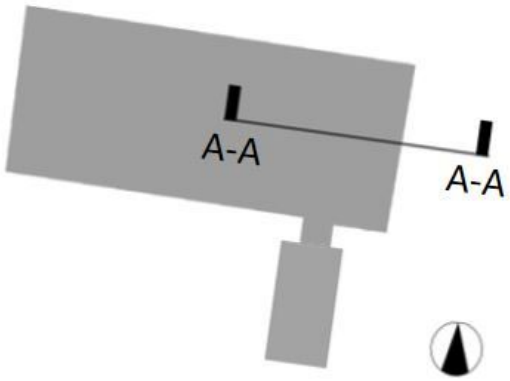


Figure 45 Floor plan showing section cut

[54] "Convention Center Construction - Pennsylvania Convention Center." Dck Worldwide. Accessed May 10, 2019. http://www.dckww.com/project/pennsylvania-convention-center/.

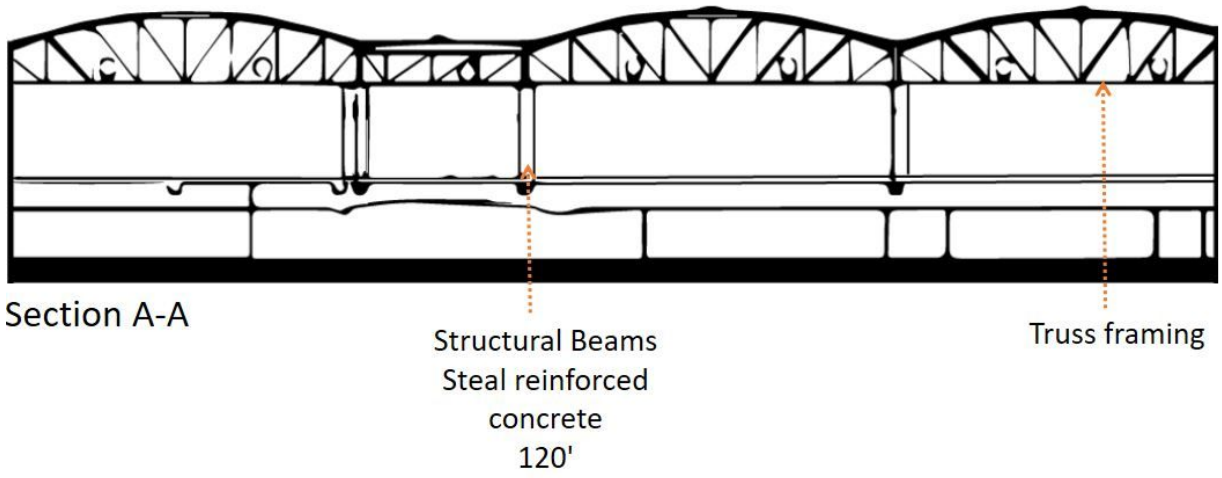


Figure 46 Section demonstrating Philadelphia Convention Center Structural Integrity

3.1.5 Large Occupancy

Currently the convention center's available space is about 1,000,000 sq. ft.[55] The Philadelphia Convention Center can hold approximately 45,522 people at maximum capacity. It also expands above the existing Reading Terminal Market on the second floor connected by a sky bridge. Exhibit halls A, B, C, and D can hold roughly 22,543 occupants and, the floor plan of Exhibit halls A,B,C and D are each individual rectangular spaces that are connected together and makeup several city blocks in width. Since, there is an open floor plan throughout the exhibit halls; the transformation of the interior space can be done quickly[56]. Elevations of the figures are found below figure 47 West Facade and Figure 48 East facade.

[55] "Convention Center Construction - Pennsylvania Convention Center." Dck Worldwide. Accessed May 10, 2019. http://www.dckww.com/project/pennsylvania-convention-center/.
[56] Convention, PA. "Capacity Charts." PA Convention. 2019. Accessed May 10, 2019. https://www.paconvention.com/meeting-professionals/floor-plans.

Figure 47 West facade

Figure 48 East facade

However, while this may seem like a large occupancy, in comparison with the population of Philadelphia, and more specifically the Center city zone the convention center in theory would only be able to aid 24% of the surrounding area[57]. Which can be see in figure 49 below which compared the Population Density of Philadelphia and center city with the Pennsylvania Convention Center Occupancy. .

[57] "Population Density for U.S. Cities Statistics." Governing. Accessed May 10, 2019. http://www.governing.com/gov-data/population-density-land-area-cities-map.html.

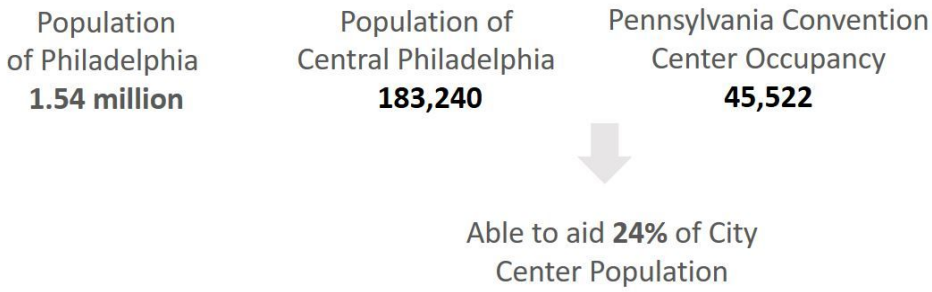


Figure 49 Population to Convention Center

3.1.6 Staging & Storage

The Philadelphia Self Service storage is located 0.9 miles from the Pennsylvania Convention Center and could serve as a designated site for supplies, in order to reduce storage inside the facility. See figure below.

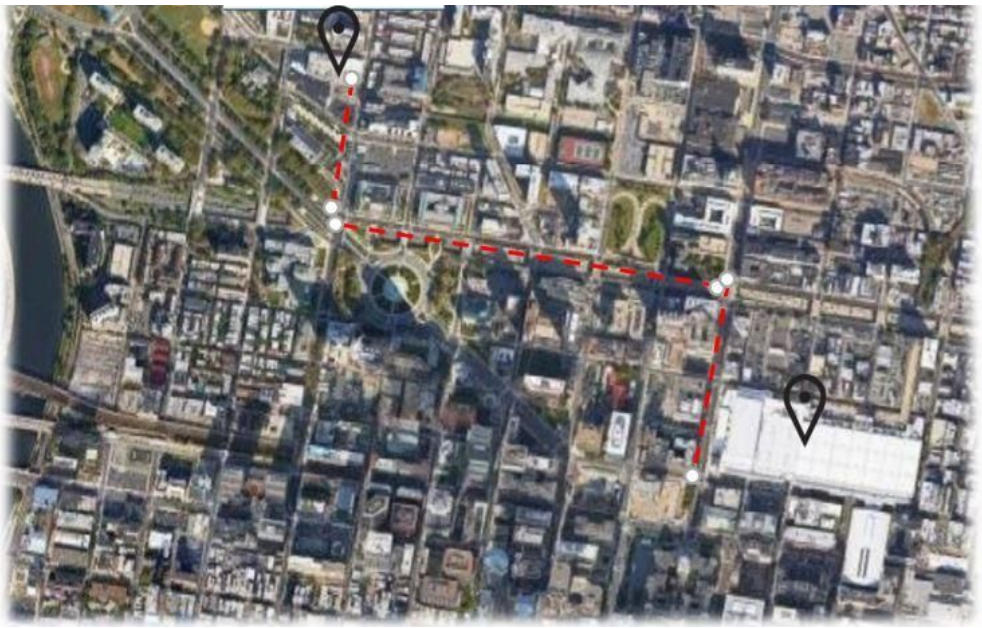


Figure 50 Storage with in Radius

3.2 Building Programming

When considering occupant flow within this space, it was important to first look at main exits and area of egress as well the new designated function of the existing space.

3.2.1 Accessibility & Emergency

As referenced in prior case studies one of the biggest concerns when power is shut off without warning, are access points to areas of the facility that usually require the use of an elevator. In the context of the Pennsylvania Convention Center vertical egress is in both elevators and stairs as well as escalators. However, in the event that one of these modes are unavailable and someone with a wheelchair needs to get from the first to the second floor the implementation of foldable ramps can be utilized over existing stairs and escalators. Currently, Roll-a-ramps can be used which are a foldable ramp that rolls up and then can be implemented where needed and comes in sizes adequate per site[58]. In Emergency situation it is also imperative that FEMA's photoluminescent material be implemented in all areas of egress and main designated exits for the facility. In the circulation section Emergency exits and allocated stairs is shown.

3.2.2 Security & Safety

The entrance for this program will be on the ground level between 12th and Arch Street in what is currently Exhibit Hall F.. Upon entrance, evacuees are greeted and then check-in after

[58] "Roll-a-ramp."Accessed 2019. https://www.rollaramp.com/.

they check in they are then ushered through security which will follow similar procedure as figure referenced from TSA. Upon passing through security, they are able to head to registration where they can receive a map of the facility, with space allocation and function, they are able to express any needs medically or physically, and are given a toiletry bag with items and extra clothes if they need them are available. Upon going through registration they head up the stairs to the second floor where the majority of the program takes place figure 51.

Figure 51 © Dominique Relei

Space Type 3.2.3

The main entrance and Exhibit hall F where security and registration takes place is on the ground floor and is marked as light green. The purple area on the diagram depicts the sleeping quarters, eatery, clinic, etc. This is demonstrated below in Figure 52.

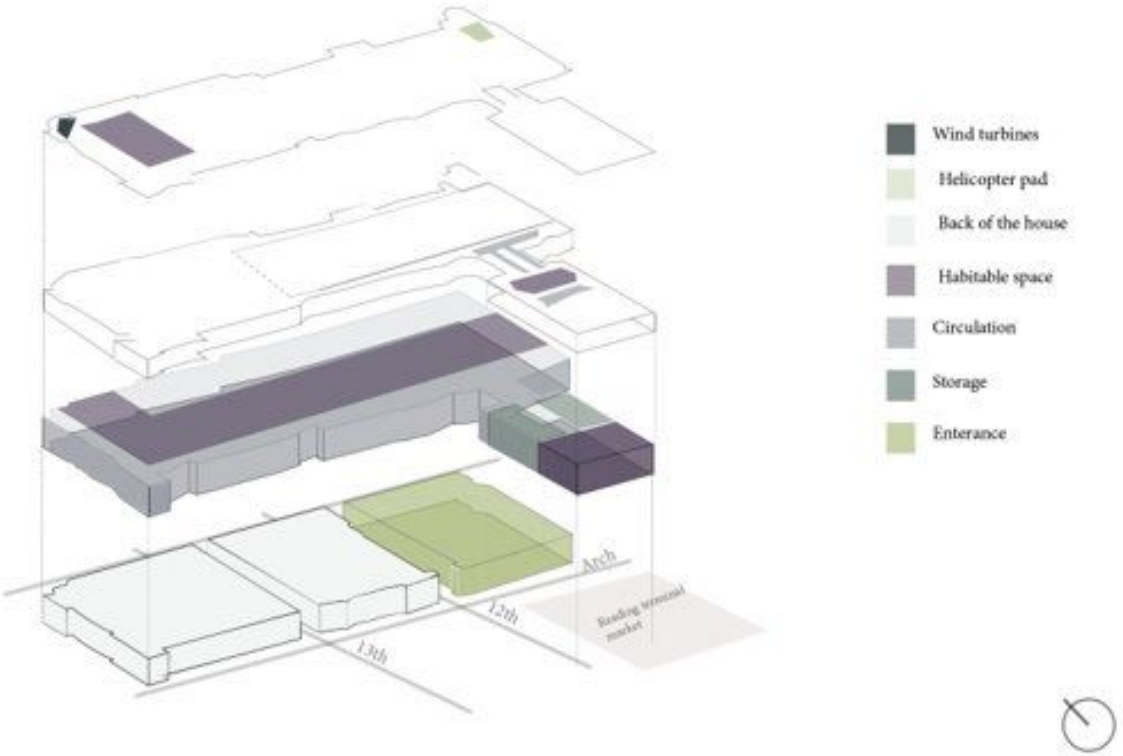


Figure 52 © Dominique Relei

Within this context a further break-down of space type by exhibit hall as well as number of occupants with furniture estimate[59]figure 53 and figure 54.

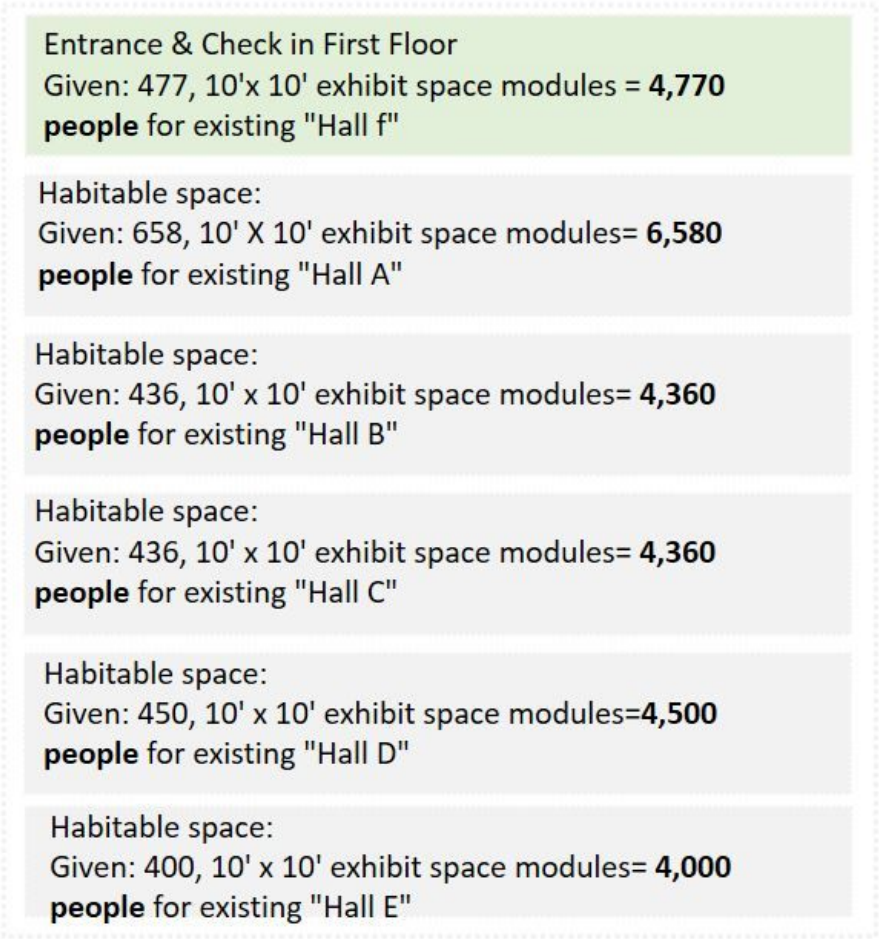


Figure 53 Estimate occupancy example with furniture using given 10’ x10’ module

[59] Convention, PA. "Capacity Charts." PA Convention. 2019. Accessed May 10, 2019. https://www.paconvention.com/meeting-professionals/floor-plans.

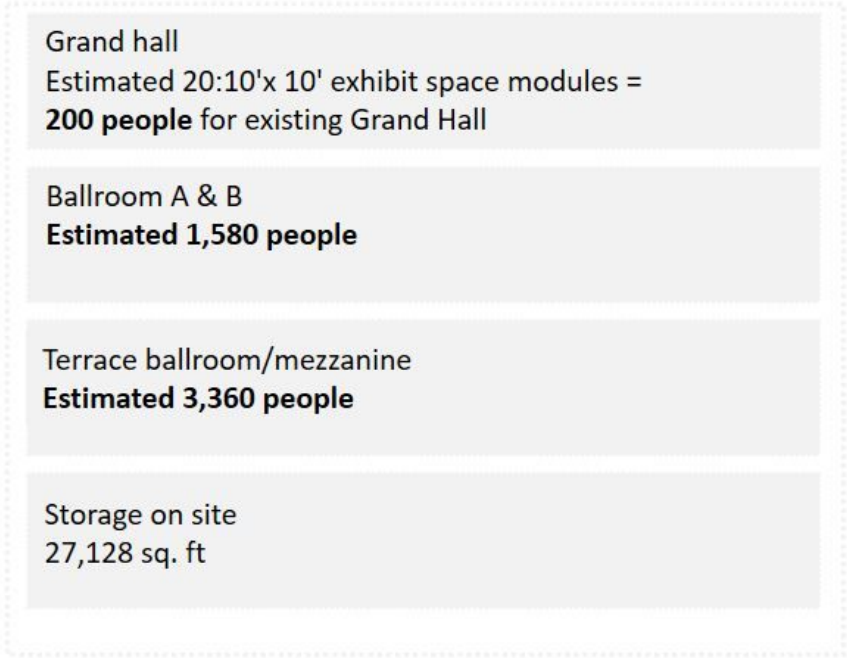


Figure 54, continuation of figure 53 data

Further application required to see what expected occupancy with designed modules is, considering that not all areas area allocated for sleeping areas. To be continued in future research.

3.2.3.1 Shared Spaces

To calculate the possible occupancy with modules I used the given information from the Pennsylvania Convention Center website of how many 10’ x 10’ temporary spaces can fit in the given Hall. For example, if there are 477, 10’ x 10’ temporary spaces and I know that at least one if not more people can fit in that space then that means that will furniture the lowest occupancy is 4,770 people for Hall F. Since, I know that my sleeping quarter modules are less than this, and

only a portion of the program is alloted for sleeping quarters, the occupancy per each space with furniture can be better understood. Exhibit Hall A is designated for sleeping quarters as well as a small clinic. Each module sleeps four people and houses two bunk beds. There are lockers in the center of the space, to encourage a sense of community amongst those staying in the spaces, they also serve a practical purpose in that, they allow more room for the occupants in their room spaces figure 55 below.

Figure 55 © Dominique Relei

3.2.3.2 Private Spaces

Exhibit Hall B features sleeping quarters in a small module. Which sleep 1-2 people each, there are lockers in the center as well. These small modules sleep 1 person in a twin size bed or 2 people in a bunk. Each sleeping area comes with a privacy screen so that although there are so many people in one space, individuals can have an area to find solitude figure 56.

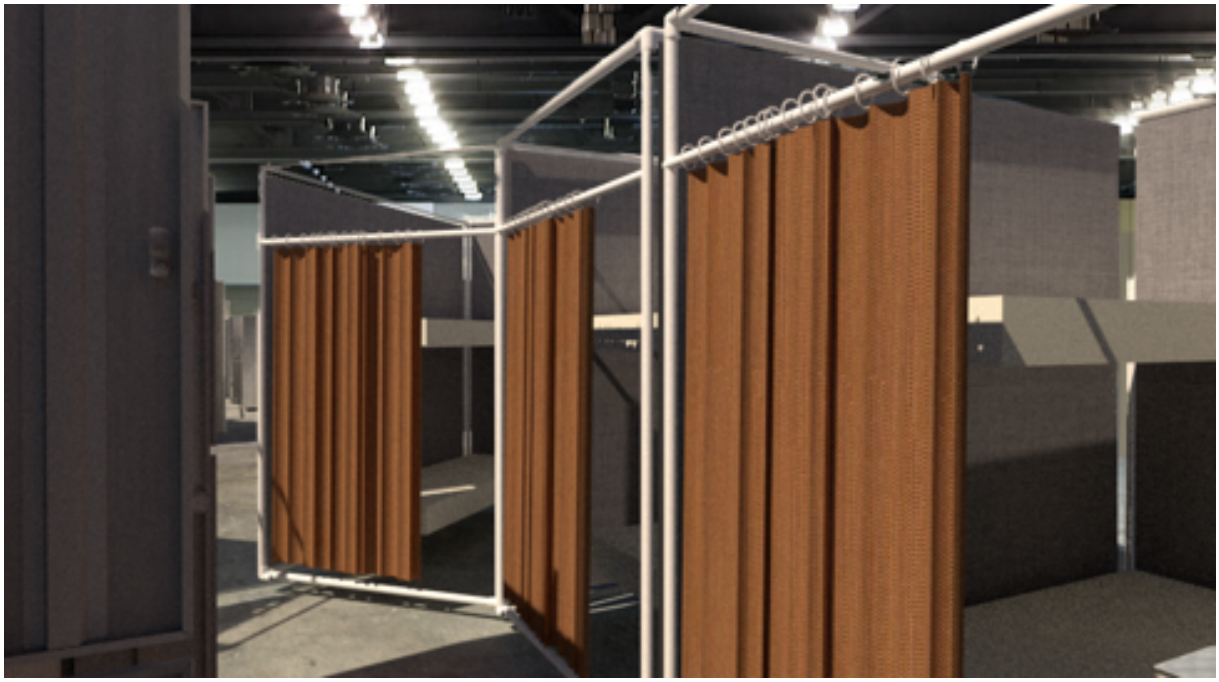


Figure 56 © Dominique Relei

3.2.3.4 Eatery

Located in Exhibit hall D, the creation of a eatery begins with forming a new space with a combination between parti-walls from the 8’ x 5’ green modules and serving stations; that is equipped with tower gardens that provide access to fresh food for those who are staying here for even a short time.The circular tables with chairs attached that fold down are quickly assemblable and can accommodate 592 people seated at a time. Next to the eatery in Exhibit hall D as well is a film area with bean bags. This space re-establishes a sense of normalcy, with the vibrant color palate and hopefully brings comfort to the occupant as they are going through this difficult time figure 57.

Figure 57 © Dominique Relei

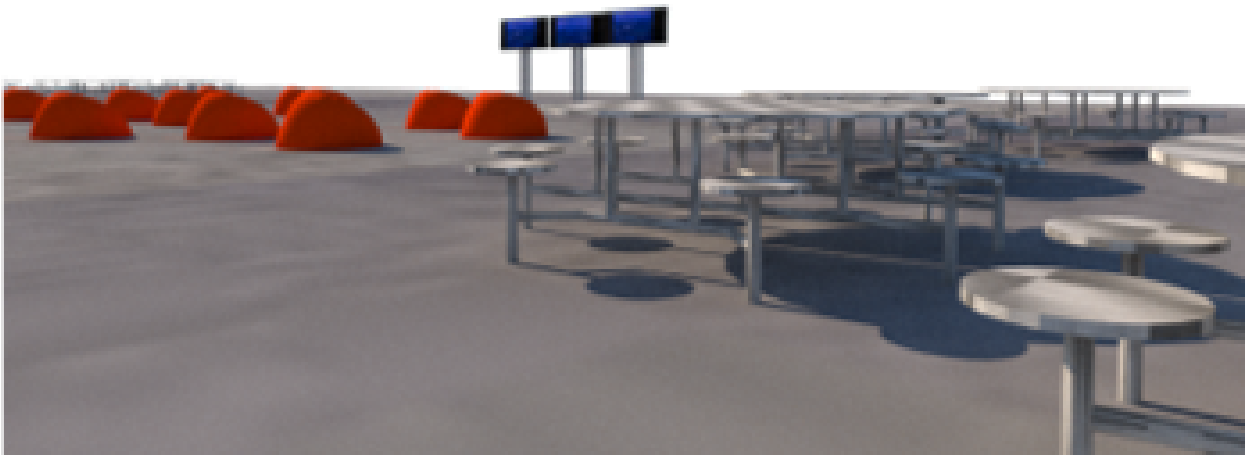


Figure 58 © Dominique Relei

3.2.3.4 Restrooms & Showers

Restrooms and Showers are located in Exhibit Hall A and B, and C, they are positioned toward the back of the facility in order to be dropped off through the garage doors that open to the loading docks on the North side of the building. 6 trailers that serve 3 people each and 32 portable privacy showers are located in Exhibit hall A, 6 trailers serving 3 people each in Hall B with 16 portable privacy showers, and 2 trailers serving 3 people each in Hall C, as well as 16 portable privacy showers see figure figure 59.

Figure 59

3.2.3.5 Clinic

The modules designed for the clinic can be arranged in any way that they are needed, the privacy screen allows for patients who would like privacy. Desks are out front to check people in and get them taken care of. For this space, an L-shape worked best. With four on one side and eight on the other, these modules are the larger of the two in order to accommodate for hospital bed, or bench with room for the doctor to come in. While the clinic is located on the second floor and the hospital in the Mezzanine, a similar approach to design can be used and implemented on a slightly larger scale figure 60.

Figure 60 © Dominique Relei

3.2.3.6 Wellbeing

A place for people who have pets, that may serve as a comfort to them, figure 61.

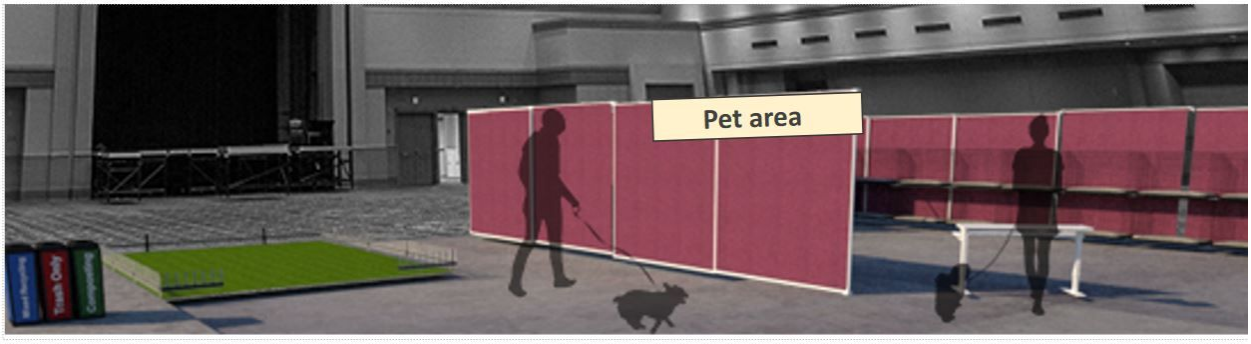
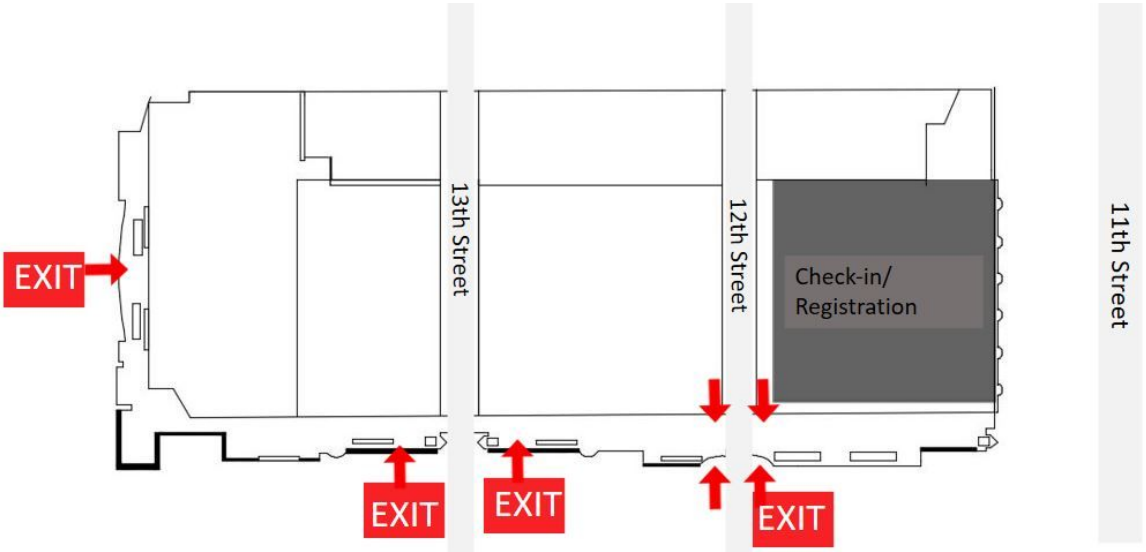


Figure 61 © Dominique Relei

3.2.4 Circulation

In order for people to find both the amenities offered as well as emergency circulation and exits they given a rough floor plan of each level which describes the function of the space and the nearest exit Figures 62-65 sketched from google earth[60].



[60] Google Earth. Accessed May 13, 2019. https://earth.google.com/web/@39.9549028,-75.1599819,33.56170486a,787.22762519d,35y,0h,45t,0r/data=ChMaEQoJL20vMDZsOWZyGAIgASgCKAI.

Figure 62 First Floor

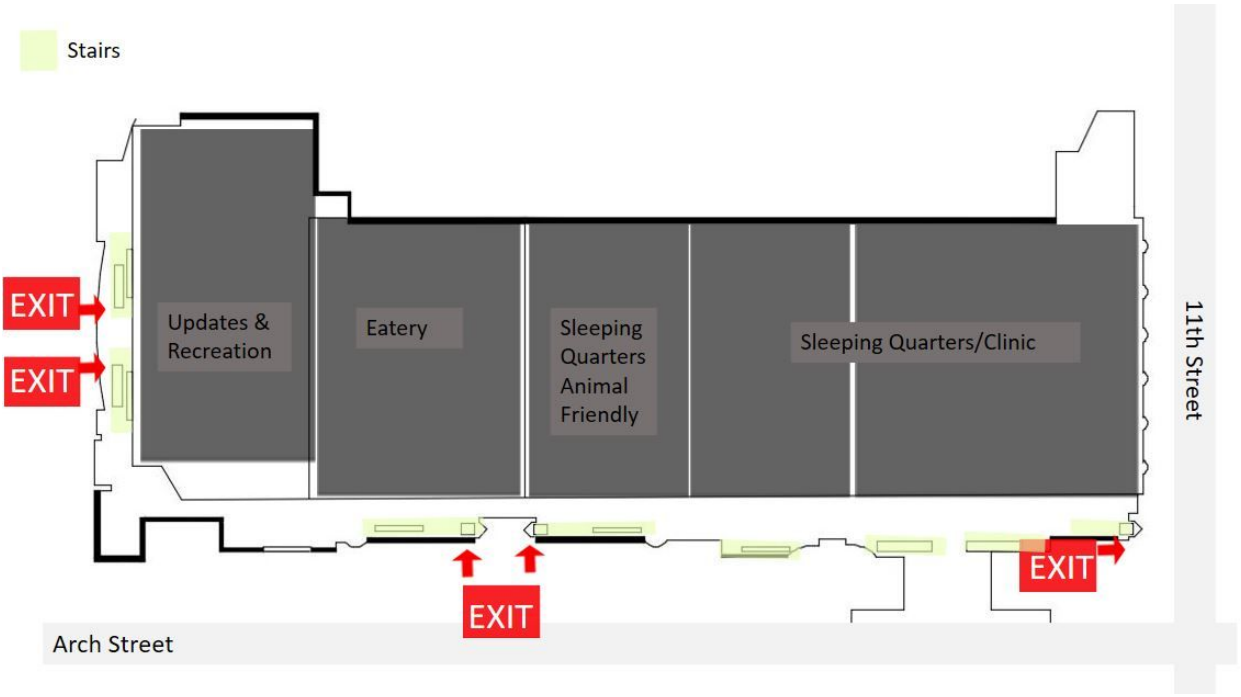


Figure 63 Second Floor

Figure 64 Mezzanine and Helicopter pad

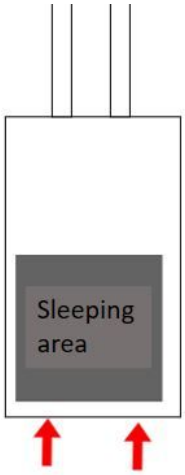


Figure 65 Above Reading terminal Market

3.2.5 Flexibility

These sleeping modules can be kept as individuals or they can be used to create spaces that bring about a sense of community and connectivity rather than isolation and rigidity. They can work around existing spaces, and can grow or shrink depending on the number needed and space given. As can be seen from the image, these existing structural columns were challenging to design spaces around, however knowing that these modules could be moved so effortlessly with a variety of options found a place within the existing space figure 66.

Figure 66 © Dominique Relei

4.0 Future Research

This topic is very vast and requires a lot of research and application. Therefore, as time did not allow the following listed topics are included in future research: wind energy generation on site, see figure below to be placed in prevailing wind direction, using storm water to generate electricity as an off-grid option, projecting operating cost, finding the time it takes to carry out program simulation for internal and external operations, and cost and retrofit as well as projected cost of programmatic elements, as well as designed module per occupancy within set space Allocation figure 67.

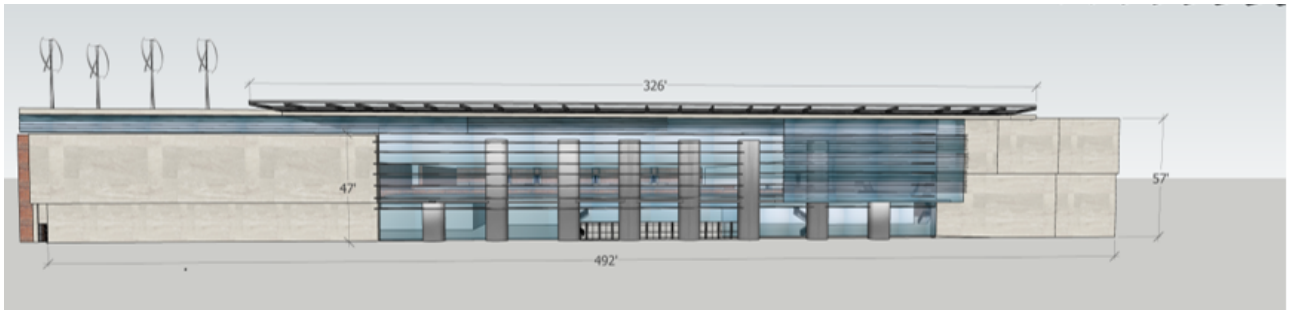


Figure 67 © Dominique Relei

Conclusion

In Conclusion the author developed a method that can effectively help disasters that could be devastating to people in society like we have seen in Katrina , that is why the author identified a method to help local governments identify primary buildings for disasters. This method successfully demonstrated how one building has been used as an effective shelter for a disaster.

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